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SUMMER RESEARCH PROGRAM -- 1996

HIGH SCHOOL APPRENTICESHIP PROGRAM FINAL REPORTS

VOLUME 12B

ARMSTRONG LABORATORY

RESEARCH & DEVELOPMENT LABORATORIES

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The United States Air Force Summer Research Program (USAF-SRP) is designed to introduce university, college, and technical institute faculty members, graduate students, and high school students to Air Force research. This is accomplished by the faculty members (Summer Faculty Research Program, (SFRP)), graduate students (Graduate Student Research Program (GSRP)), and high school students (High School Apprenticeship Program (HSAP)) being selected on a nationally advertised competitive basis during the summer intersession period to perform research at Air Force Research Laboratory (AFRL) Technical Directorates, Air Force Air Logistics Centers (ALC), and other AF Laboratories. This volume consists of a program overview, program management statistics, and the final technical reports from the HSAP participants at the Armstrong Laboratory.

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PREFACE

Reports in this volume are numbered consecutively beginning with number 1. Each report is paginated with the report number followed by consecutive page numbers, e.g., 1-1, 1-2, 1-3; 2-1, 2-2, 2-3.

Due to its length, Volume 12 is bound in two parts, 12A and 12B. Volume 12A contains #1-22. Volume 12B contains reports #23-36. The Table of Contents for Volume 12 is included in both parts.

This document is one of a set of 16 volumes describing the 1996 AFOSR Summer Research Program. The following volumes comprise the set:

VOLUME	TITLE
1	Program Management Report
	Summer Faculty Research Program (SFRP) Reports
2A & 2B	Armstrong Laboratory
3A & 3B	Phillips Laboratory
4	Rome Laboratory
5A, 5B, & 5C	Wright Laboratory
6	Arnold Engineering Development Center, Frank J. Seiler Research Laboratory, and Wilford Hall Medical Center
	Graduate Student Research Program (GSRP) Reports
7A & 7B	Armstrong Laboratory
8	Phillips Laboratory
9	Rome Laboratory
10A & 10B	Wright Laboratory
11	Arnold Engineering Development Center, U.S. Air Force Academy, Air Logistic Centers, and Wilford Hall Medical Center
	High School Apprenticeship Program (HSAP) Reports
12A & 12B	Armstrong Laboratory
13	Phillips Laboratory
14	Rome Laboratory
15A & 15B	Wright Laboratory
16	Arnold Engineering Development Center

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INTRODUCTION

The Summer Research Program (SRP), sponsored by the Air Force Office of Scientific Research (AFOSR), offers paid opportunities for university faculty, graduate students, and high school students to conduct research in U.S. Air Force research laboratories nationwide during the summer.

Introduced by AFOSR in 1978, this innovative program is based on the concept of teaming academic researchers with Air Force scientists in the same disciplines using laboratory facilities and equipment not often available at associates' institutions.

The Summer Faculty Research Program (SFRP) is open annually to approximately 150 faculty members with at least two years of teaching and/or research experience in accredited U.S. colleges, universities, or technical institutions. SFRP associates must be either U.S. citizens or permanent residents.

The Graduate Student Research Program (GSRP) is open annually to approximately 100 graduate students holding a bachelor's or a master's degree; GSRP associates must be U.S. citizens enrolled full time at an accredited institution.

The High School Apprentice Program (HSAP) annually selects about 125 high school students located within a twenty mile commuting distance of participating Air Force laboratories.

AFOSR also offers its research associates an opportunity, under the Summer Research Extension Program (SREP), to continue their AFOSR-sponsored research at their home institutions through the award of research grants. In 1994 the maximum amount of each grant was increased from \$20,000 to \$25,000, and the number of AFOSR-sponsored grants decreased from 75 to 60. A separate annual report is compiled on the SREP.

The numbers of projected summer research participants in each of the three categories and SREP "grants" are usually increased through direct sponsorship by participating laboratories.

AFOSR's SRP has well served its objectives of building critical links between Air Force research laboratories and the academic community, opening avenues of communications and forging new research relationships between Air Force and academic technical experts in areas of national interest, and strengthening the nation's efforts to sustain careers in science and engineering. The success of the SRP can be gauged from its growth from inception (see Table 1) and from the favorable responses the 1996 participants expressed in end-of-tour SRP evaluations (Appendix B).

AFOSR contracts for administration of the SRP by civilian contractors. The contract was first awarded to Research & Development Laboratories (RDL) in September 1990. After completion of the 1990 contract, RDL (in 1993) won the recompetition for the basic year and four 1-year options.

2. PARTICIPATION IN THE SUMMER RESEARCH PROGRAM

The SRP began with faculty associates in 1979; graduate students were added in 1982 and high school students in 1986. The following table shows the number of associates in the program each year.

YEAR	SRP Participation, by Year			TOTAL
	SFRP	GSRP	HSAP	
1979	70			70
1980	87			87
1981	87			87
1982	91	17		108
1983	101	53		154
1984	152	84		236
1985	154	92		246
1986	158	100	42	300
1987	159	101	73	333
1988	153	107	101	361
1989	168	102	103	373
1990	165	121	132	418
1991	170	142	132	444
1992	185	121	159	464
1993	187	117	136	440
1994	192	117	133	442
1995	190	115	137	442
1996	188	109	138	435

Beginning in 1993, due to budget cuts, some of the laboratories weren't able to afford to fund as many associates as in previous years. Since then, the number of funded positions has remained fairly constant at a slightly lower level.

3. RECRUITING AND SELECTION

The SRP is conducted on a nationally advertised and competitive-selection basis. The advertising for faculty and graduate students consisted primarily of the mailing of 8,000 52-page SRP brochures to chairpersons of departments relevant to AFOSR research and to administrators of grants in accredited universities, colleges, and technical institutions. Historically Black Colleges and Universities (HBCUs) and Minority Institutions (MIs) were included. Brochures also went to all participating USAF laboratories, the previous year's participants, and numerous individual requesters (over 1000 annually).

RDL placed advertisements in the following publications: *Black Issues in Higher Education, Winds of Change,* and *IEEE Spectrum.* Because no participants list either *Physics Today* or *Chemical & Engineering News* as being their source of learning about the program for the past several years, advertisements in these magazines were dropped, and the funds were used to cover increases in brochure printing costs.

High school applicants can participate only in laboratories located no more than 20 miles from their residence. Tailored brochures on the HSAP were sent to the head counselors of 180 high schools in the vicinity of participating laboratories, with instructions for publicizing the program in their schools. High school students selected to serve at Wright Laboratory's Armament Directorate (Eglin Air Force Base, Florida) serve eleven weeks as opposed to the eight weeks normally worked by high school students at all other participating laboratories.

Each SFRP or GSRP applicant is given a first, second, and third choice of laboratory. High school students who have more than one laboratory or directorate near their homes are also given first, second, and third choices.

Laboratories make their selections and prioritize their nominees. AFOSR then determines the number to be funded at each laboratory and approves laboratories' selections.

Subsequently, laboratories use their own funds to sponsor additional candidates. Some selectees do not accept the appointment, so alternate candidates are chosen. This multi-step selection procedure results in some candidates being notified of their acceptance after scheduled deadlines. The total applicants and participants for 1996 are shown in this table.

1996 Applicants and Participants			
PARTICIPANT CATEGORY	TOTAL APPLICANTS	SELECTEES	DECLINING SELECTEES
SFRP	572	188	39
(HBCU/MI)	(119)	(27)	(5)
GSRP	235	109	7
(HBCU/MI)	(18)	(7)	(1)
HSAP	474	138	8
TOTAL	1281	435	54

4. SITE VISITS

During June and July of 1996, representatives of both AFOSR/NI and RDL visited each participating laboratory to provide briefings, answer questions, and resolve problems for both laboratory personnel and participants. The objective was to ensure that the SRP would be as constructive as possible for all participants. Both SRP participants and RDL representatives found these visits beneficial. At many of the laboratories, this was the only opportunity for all participants to meet at one time to share their experiences and exchange ideas.

5. HISTORICALLY BLACK COLLEGES AND UNIVERSITIES AND MINORITY INSTITUTIONS (HBCU/MIs)

Before 1993, an RDL program representative visited from seven to ten different HBCU/Mis annually to promote interest in the SRP among the faculty and graduate students. These efforts were marginally effective, yielding a doubling of HBCI/MI applicants. In an effort to achieve AFOSR's goal of 10% of all applicants and selectees being HBCU/MI qualified, the RDL team decided to try other avenues of approach to increase the number of qualified applicants. Through the combined efforts of the AFOSR Program Office at Bolling AFB and RDL, two very active minority groups were found, HACU (Hispanic American Colleges and Universities) and AISES (American Indian Science and Engineering Society). RDL is in communication with representatives of each of these organizations on a monthly basis to keep up with the their activities and special events. Both organizations have widely-distributed magazines/quarterlies in which RDL placed ads.

Since 1994 the number of both SFRP and GSRP HBCU/MI applicants and participants has increased ten-fold, from about two dozen SFRP applicants and a half dozen selectees to over 100 applicants and two dozen selectees, and a half-dozen GSRP applicants and two or three selectees to 18 applicants and 7 or 8 selectees. Since 1993, the SFRP had a two-fold applicant increase and a two-fold selectee increase. Since 1993, the GSRP had a three-fold applicant increase and a three to four-fold increase in selectees.

In addition to RDL's special recruiting efforts, AFOSR attempts each year to obtain additional funding or use leftover funding from cancellations the past year to fund HBCU/MI associates. This year, 5 HBCU/MI SFRPs declined after they were selected (and there was no one qualified to replace them with). The following table records HBCU/MI participation in this program.

SRP HBCU/MI Participation, By Year				
YEAR	SFRP		GSRP	
	Applicants	Participants	Applicants	Participants
1985	76	23	15	11
1986	70	18	20	10
1987	82	32	32	10
1988	53	17	23	14
1989	39	15	13	4
1990	43	14	17	3
1991	42	13	8	5
1992	70	13	9	5
1993	60	13	6	2
1994	90	16	11	6
1995	90	21	20	8
1996	119	27	18	7

6. SRP FUNDING SOURCES

Funding sources for the 1996 SRP were the AFOSR-provided slots for the basic contract and laboratory funds. Funding sources by category for the 1996 SRP selected participants are shown here.

1996 SRP FUNDING CATEGORY	SFRP	GSRP	HSAP
AFOSR Basic Allocation Funds	141	85	123
USAF Laboratory Funds	37	19	15
HBCU/MI By AFOSR (Using Procured Addn'l Funds)	10	5	0
TOTAL	188	109	138

SFRP - 150 were selected, but nine canceled too late to be replaced.
GSRP - 90 were selected, but five canceled too late to be replaced (10 allocations for the ALCs were withheld by AFOSR.)
HSAP - 125 were selected, but two canceled too late to be replaced.

7. COMPENSATION FOR PARTICIPANTS

Compensation for SRP participants, per five-day work week, is shown in this table.

1996 SRP Associate Compensation

PARTICIPANT CATEGORY	1991	1992	1993	1994	1995	1996
Faculty Members	$690	$718	$740	$740	$740	$770
Graduate Student (Master's Degree)	$425	$442	$455	$455	$455	$470
Graduate Student (Bachelor's Degree)	$365	$380	$391	$391	$391	$400
High School Student (First Year)	$200	$200	$200	$200	$200	$200
High School Student (Subsequent Years)	$240	$240	$240	$240	$240	$240

The program also offered associates whose homes were more than 50 miles from the laboratory an expense allowance (seven days per week) of $50/day for faculty and $40/day for graduate students. Transportation to the laboratory at the beginning of their tour and back to their home destinations at the end was also reimbursed for these participants. Of the combined SFRP and

GSRP associates, 65 % (194 out of 297) claimed travel reimbursements at an average round-trip cost of $780.

Faculty members were encouraged to visit their laboratories before their summer tour began. All costs of these orientation visits were reimbursed. Forty-five percent (85 out of 188) of faculty associates took orientation trips at an average cost of $444. By contrast, in 1993, 58 % of SFRP associates took orientation visits at an average cost of $685; that was the highest percentage of associates opting to take an orientation trip since RDL has administered the SRP, and the highest average cost of an orientation trip. These 1993 numbers are included to show the fluctuation which can occur in these numbers for planning purposes.

Program participants submitted biweekly vouchers countersigned by their laboratory research focal point, and RDL issued paychecks so as to arrive in associates' hands two weeks later.

In 1996, RDL implemented direct deposit as a payment option for SFRP and GSRP associates. There were some growing pains. Of the 128 associates who opted for direct deposit, 17 did not check to ensure that their financial institutions could support direct deposit (and they couldn't), and eight associates never did provide RDL with their banks' ABA number (direct deposit bank routing number), so only 103 associates actually participated in the direct deposit program. The remaining associates received their stipend and expense payments via checks sent in the US mail.

HSAP program participants were considered actual RDL employees, and their respective state and federal income tax and Social Security were withheld from their paychecks. By the nature of their independent research, SFRP and GSRP program participants were considered to be consultants or independent contractors. As such, SFRP and GSRP associates were responsible for their own income taxes, Social Security, and insurance.

8. CONTENTS OF THE 1996 REPORT

The complete set of reports for the 1996 SRP includes this program management report (Volume 1) augmented by fifteen volumes of final research reports by the 1996 associates, as indicated below:

1996 SRP Final Report Volume Assignments

LABORATORY	SFRP	GSRP	HSAP
Armstrong	2	7	12
Phillips	3	8	13
Rome	4	9	14
Wright	5A, 5B	10	15
AEDC, ALCs, WHMC	6	11	16

APPENDIX A -- PROGRAM STATISTICAL SUMMARY

A. Colleges/Universities Represented

Selected SFRP associates represented 169 different colleges, universities, and institutions, GSRP associates represented 95 different colleges, universities, and institutions.

B. States Represented

SFRP -Applicants came from 47 states plus Washington D.C. and Puerto Rico. Selectees represent 44 states plus Puerto Rico.

GSRP - Applicants came from 44 states and Puerto Rico. Selectees represent 32 states.

HSAP - Applicants came from thirteen states. Selectees represent nine states.

Total Number of Participants	
SFRP	188
GSRP	109
HSAP	138
TOTAL	435

Degrees Represented			
	SFRP	GSRP	TOTAL
Doctoral	184	1	185
Master's	4	48	52
Bachelor's	0	60	60
TOTAL	188	109	297

SFRP Academic Titles	
Assistant Professor	79
Associate Professor	59
Professor	42
Instructor	3
Chairman	0
Visiting Professor	1
Visiting Assoc. Prof.	0
Research Associate	4
TOTAL	188

Source of Learning About the SRP		
Category	Applicants	Selectees
Applied/participated in prior years	28%	34%
Colleague familiar with SRP	19%	16%
Brochure mailed to institution	23%	17%
Contact with Air Force laboratory	17%	23%
IEEE Spectrum	2%	1%
BIIHE	1%	1%
Other source	10%	8%
TOTAL	100%	100%

APPENDIX B – SRP EVALUATION RESPONSES

1. OVERVIEW

Evaluations were completed and returned to RDL by four groups at the completion of the SRP. The number of respondents in each group is shown below.

Table B-1. Total SRP Evaluations Received

Evaluation Group	Responses
SFRP & GSRPs	275
HSAPs	113
USAF Laboratory Focal Points	84
USAF Laboratory HSAP Mentors	6

All groups indicate unanimous enthusiasm for the SRP experience.

The summarized recommendations for program improvement from both associates and laboratory personnel are listed below:

A. Better preparation on the labs' part prior to associates' arrival (i.e., office space, computer assets, clearly defined scope of work).

B. Faculty Associates suggest higher stipends for SFRP associates.

C. Both HSAP Air Force laboratory mentors and associates would like the summer tour extended from the current 8 weeks to either 10 or 11 weeks; the groups state it takes 4-6 weeks just to get high school students up-to-speed on what's going on at laboratory. (Note: this same argument was used to raise the faculty and graduate student participation time a few years ago.)

2. 1996 USAF LABORATORY FOCAL POINT (LFP) EVALUATION RESPONSES

The summarized results listed below are from the 84 LFP evaluations received.

1. LFP evaluations received and associate preferences:

Table B-2. Air Force LFP Evaluation Responses (By Type)

		How Many Associates Would You Prefer To Get ? (% Response)											
		SFRP				GSRP (w/Univ Professor)				GSRP (w/o Univ Professor)			
Lab	**Evals Recv'd**	**0**	**1**	**2**	**3+**	**0**	**1**	**2**	**3+**	**0**	**1**	**2**	**3+**
AEDC	0	-	-	-	-	-	-	-	-	-	-	-	-
WHMC	0	-	-	-	-	-	-	-	-	-	-	-	-
AL	7	28	28	28	14	54	14	28	0	86	0	14	0
FJSRL	1	0	100	0	0	100	0	0	0	0	100	0	0
PL	25	40	40	16	4	88	12	0	0	84	12	4	0
RL	5	60	40	0	0	80	10	0	0	100	0	0	0
WL	46	30	43	20	6	78	17	4	0	93	4	2	0
Total	84	32%	50%	13%	5%	80%	11%	6%	0%	73%	23%	4%	0%

LFP Evaluation Summary. The summarized responses, by laboratory, are listed on the following page. LFPs were asked to rate the following questions on a scale from 1 (below average) to 5 (above average).

2. LFPs involved in SRP associate application evaluation process:
   a. Time available for evaluation of applications:
   b. Adequacy of applications for selection process:
3. Value of orientation trips:
4. Length of research tour:
5. a. Benefits of associate's work to laboratory:
   b. Benefits of associate's work to Air Force:
6. a. Enhancement of research qualifications for LFP and staff:
   b. Enhancement of research qualifications for SFRP associate:
   c. Enhancement of research qualifications for GSRP associate:
7. a. Enhancement of knowledge for LFP and staff:
   b. Enhancement of knowledge for SFRP associate:
   c. Enhancement of knowledge for GSRP associate:
8. Value of Air Force and university links:
9. Potential for future collaboration:
10. a. Your working relationship with SFRP:
    b. Your working relationship with GSRP:
11. Expenditure of your time worthwhile:

(Continued on next page)

12. Quality of program literature for associate:
13. a. Quality of RDL's communications with you:
    b. Quality of RDL's communications with associates:
14. Overall assessment of SRP:

Table B-3. Laboratory Focal Point Reponses to above questions

	AEDC	*AL*	*FJSRL*	*PL*	*RL*	*WHMC*	*WL*
# Evals Recv'd	0	7	1	14	5	0	46
Question #							
2	-	86 %	0 %	88 %	80 %	-	85 %
2a	-	4.3	n/a	3.8	4.0	-	3.6
2b	-	4.0	n/a	3.9	4.5	-	4.1
3	-	4.5	n/a	4.3	4.3	-	3.7
4	-	4.1	4.0	4.1	4.2	-	3.9
5a	-	4.3	5.0	4.3	4.6	-	4.4
5b	-	4.5	n/a	4.2	4.6	-	4.3
6a	-	4.5	5.0	4.0	4.4	-	4.3
6b	-	4.3	n/a	4.1	5.0	-	4.4
6c	-	3.7	5.0	3.5	5.0	-	4.3
7a	-	4.7	5.0	4.0	4.4	-	4.3
7b	-	4.3	n/a	4.2	5.0	-	4.4
7c	-	4.0	5.0	3.9	5.0	-	4.3
8	-	4.6	4.0	4.5	4.6	-	4.3
9	-	4.9	5.0	4.4	4.8	-	4.2
10a	-	5.0	n/a	4.6	4.6	-	4.6
10b	-	4.7	5.0	3.9	5.0	-	4.4
11	-	4.6	5.0	4.4	4.8	-	4.4
12	-	4.0	4.0	4.0	4.2	-	3.8
13a	-	3.2	4.0	3.5	3.8	-	3.4
13b	-	3.4	4.0	3.6	4.5	-	3.6
14	-	4.4	5.0	4.4	4.8	-	4.4

3. 1996 SFRP & GSRP EVALUATION RESPONSES

The summarized results listed below are from the 257 SFRP/GSRP evaluations received.

Associates were asked to rate the following questions on a scale from 1 (below average) to 5 (above average) - by Air Force base results and over-all results of the 1996 evaluations are listed after the questions.

1. The match between the laboratories research and your field:
2. Your working relationship with your LFP:
3. Enhancement of your academic qualifications:
4. Enhancement of your research qualifications:
5. Lab readiness for you: LFP, task, plan:
6. Lab readiness for you: equipment, supplies, facilities:
7. Lab resources:
8. Lab research and administrative support:
9. Adequacy of brochure and associate handbook:
10. RDL communications with you:
11. Overall payment procedures:
12. Overall assessment of the SRP:
13.
    a. Would you apply again?
    b. Will you continue this or related research?
14. Was length of your tour satisfactory?
15. Percentage of associates who experienced difficulties in finding housing:
16. Where did you stay during your SRP tour?
    a. At Home:
    b. With Friend:
    c. On Local Economy:
    d. Base Quarters:
17. Value of orientation visit:
    a. Essential:
    b. Convenient:
    c. Not Worth Cost:
    d. Not Used:

SFRP and GSRP associate's responses are listed in tabular format on the following page.

Table B-4. 1996 SFRP & GSRP Associate Responses to SRP Evaluation

	Arnold	Brooks	Edwards	Eglin	Griffis	Hanscom	Kelly	Kirtland	Lackland	Robins	Tyndall	WPAFB	average
# res	6	48	6	14	31	19	3	32	1	2	10	85	257
1	4.8	4.4	4.6	4.7	4.4	4.9	4.6	4.6	5.0	5.0	4.0	4.7	4.6
2	5.0	4.6	4.1	4.9	4.7	4.7	5.0	4.7	5.0	5.0	4.6	4.8	4.7
3	4.5	4.4	4.0	4.6	4.3	4.2	4.3	4.4	5.0	5.0	4.5	4.3	4.4
4	4.3	4.5	3.8	4.6	4.4	4.4	4.3	4.6	5.0	4.0	4.4	4.5	4.5
5	4.5	4.3	3.3	4.8	4.4	4.5	4.3	4.2	5.0	5.0	3.9	4.4	4.4
6	4.3	4.3	3.7	4.7	4.4	4.5	4.0	3.8	5.0	5.0	3.8	4.2	4.2
7	4.5	4.4	4.2	4.8	4.5	4.3	4.3	4.1	5.0	5.0	4.3	4.3	4.4
8	4.5	4.6	3.0	4.9	4.4	4.3	4.3	4.5	5.0	5.0	4.7	4.5	4.5
9	4.7	4.5	4.7	4.5	4.3	4.5	4.7	4.3	5.0	5.0	4.1	4.5	4.5
10	4.2	4.4	4.7	4.4	4.1	4.1	4.0	4.2	5.0	4.5	3.6	4.4	4.3
11	3.8	4.1	4.5	4.0	3.9	4.1	4.0	4.0	3.0	4.0	3.7	4.0	4.0
12	5.7	4.7	4.3	4.9	4.5	4.9	4.7	4.6	5.0	4.5	4.6	4.5	4.6
Numbers below are percentages													
13a	83	90	83	93	87	75	100	81	100	100	100	86	87
13b	100	89	83	100	94	98	100	94	100	100	100	94	93
14	83	96	100	90	87	80	100	92	100	100	70	84	88
15	17	6	0	33	20	76	33	25	0	100	20	8	39
16a	-	26	17	9	38	23	33	4	-	-	-	30	
16b	100	33	-	40	-	8	-	-	-	-	36	2	
16c	-	41	83	40	62	69	67	96	100	100	64	68	
16d	-	-	-	-	-	-	-	-	-	-	-	0	
17a	-	33	100	17	50	14	67	39	-	50	40	31	35
17b	-	21	-	17	10	14	-	24	-	50	20	16	16
17c	-	-	-	-	10	7	-	-	-	-	-	2	3
17d	100	46	-	66	30	69	33	37	100	-	40	51	46

4. 1996 USAF LABORATORY HSAP MENTOR EVALUATION RESPONSES

Not enough evaluations received (5 total) from Mentors to do useful summary.

5. 1996 HSAP EVALUATION RESPONSES

The summarized results listed below are from the 113 HSAP evaluations received.

HSAP apprentices were asked to rate the following questions on a scale from 1 (below average) to 5 (above average)

1. Your influence on selection of topic/type of work.
2. Working relationship with mentor, other lab scientists.
3. Enhancement of your academic qualifications.
4. Technically challenging work.
5. Lab readiness for you: mentor, task, work plan, equipment.
6. Influence on your career.
7. Increased interest in math/science.
8. Lab research & administrative support.
9. Adequacy of RDL's Apprentice Handbook and administrative materials.
10. Responsiveness of RDL communications.
11. Overall payment procedures.
12. Overall assessment of SRP value to you.
13. Would you apply again next year? Yes (92 %)
14. Will you pursue future studies related to this research? Yes (68 %)
15. Was Tour length satisfactory? Yes (82 %)

	Arnold	Brooks	Edwards	Eglin	Griffiss	Hanscom	Kirtland	Tyndall	WPAFB	Totals
# resp	5	19	7	15	13	2	7	5	40	113
1	2.8	3.3	3.4	3.5	3.4	4.0	3.2	3.6	3.6	3.4
2	4.4	4.6	4.5	4.8	4.6	4.0	4.4	4.0	4.6	4.6
3	4.0	4.2	4.1	4.3	4.5	5.0	4.3	4.6	4.4	4.4
4	3.6	3.9	4.0	4.5	4.2	5.0	4.6	3.8	4.3	4.2
5	4.4	4.1	3.7	4.5	4.1	3.0	3.9	3.6	3.9	4.0
6	3.2	3.6	3.6	4.1	3.8	5.0	3.3	3.8	3.6	3.7
7	2.8	4.1	4.0	3.9	3.9	5.0	3.6	4.0	4.0	3.9
8	3.8	4.1	4.0	4.3	4.0	4.0	4.3	3.8	4.3	4.2
9	4.4	3.6	4.1	4.1	3.5	4.0	3.9	4.0	3.7	3.8
10	4.0	3.8	4.1	3.7	4.1	4.0	3.9	2.4	3.8	3.8
11	4.2	4.2	3.7	3.9	3.8	3.0	3.7	2.6	3.7	3.8
12	4.0	4.5	4.9	4.6	4.6	5.0	4.6	4.2	4.3	4.5
Numbers below are percentages										
13	60%	95%	100%	100%	85%	100%	100%	100%	90%	92%
14	20%	80%	71%	80%	54%	100%	71%	80%	65%	68%
15	100%	70%	71%	100%	100%	50%	86%	60%	80%	82%

RAID: REDUNDANT ARRAY OF INDEPENDENT/INEXPENSIVE DISKS

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Final Report for:
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Armstrong Laboratory

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RAID: REDUNDANT ARRAY OF INDEPENDENT/INEXPENSIVE DISKS

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Abstract

The input/output (I/O) systems of most computers have nowhere near the speed of the central processing unit. One solution to this problem is a redundant array of independent/inexpensive disks (RAID), which can increase the speed of an I/O system by breaking apart requests and letting each disk on the array handle a part. The original five "levels" (configurations) along with several newer configurations are detailed. The two basic ways of getting a RAID system, buying one and setting one up yourself, are explained along with how to choose the best "level". Finally two projects that the Instructional Systems Research Branch is working on , XAIDA (Experimental Advanced Instructional Design Associate) and TEEM (Training Efficiency and Effectiveness Methodology), are described and how a RAID system could help them is explained.

RAID: REDUNDANT ARRAY OF INDEPENDENT/INEXPENSIVE DISKS

David J. Miller

Introduction

Central processing units (CPUs) have made great advancements over the past decade. Even though input/output (I/O) systems have increased in speed and capacity, their advancements are far outweighed by the processor advancements. The end result is the so called I/O bottleneck, when processors operate at less then full capacity or even sit idle while the slower I/O systems read and write data. Little can be done to improve the speed of I/O systems because they depend on fixed disks -- mechanical devices. Manufacturers just cannot keep making the actuator which moves the read/write head across the surface of the disk faster.

Another concern is data availability. Many times, computers are the main repositories for critical data. If the hard disk crashes it could take a long time to retype all the data in and even then some new data still may be lost. Data integrity is still another concern. Data integrity refers to the ability of a computer to recover from a failure without corrupting data, while data availability refers to the ability of a computer to recover from a failure without losing data. One answer to these problems is using RAIDs (redundant arrays of independent/inexpensive disks) as opposed to SLEDs (single large expensive disks).

What is RAID?

RAID is a category of disk arrays (two or more disks working as one) that improve tolerance toward disk failure. They provide this increased tolerance in a variety of different methods. Each method is assigned a different "level". The term RAID first appeared in 1987 in papers written by Professors Patterson, Gibson, and Katz of the University of California at Berkeley. At that time RAID meant redundant array of *inexpensive* disks and was designed to be a way to get a large amount of memory out of a small cost. In the years after that RAIDs began losing their edge in cost over SLEDs and began to be used more for their high performance and data availability (Invincible Technologies Corporation, 1996). That was when RAID began to mean redundant array of *independent* disks. In August 1992, the RAID advisory board (RAB) was founded. It was founded with the goal of promoting the understanding and utilization of RAID and related storage technologies (RAID Advisory Board, 1996). It accomplishes this through a variety of different methods including providing publications, holding conferences, and staging RAID technology centers at trade shows and conferences. RAB's membership has grown from 8 to over 50 since its founding (RAID advisory board, 1996). Its members include RAID suppliers, computer suppliers, manufacturers, companies, research firms, and universities.

What are the RAID levels?

In the original Berkeley papers, five RAID levels were defined (levels 1 through 5). The use of levels is misleading, because higher levels are not necessarily any better. They just perform their function in a different way. These are the five RAID levels:

RAID 1 is also known as mirroring or shadowing. All data is written to two separate drives giving the array complete redundancy and therefore high data availability. If one disk crashes, the other still retains the data that may be written back onto the failed disk or a substitute one. This setup can also read quicker, because if both disks begin looking for the data, one will probably find it before a single disk alone would. Two reads may also be done simultaneously. The drawback to this setup is that it requires double the physical storage required since half will be used as backup. Which means it is twice as expensive. Also, this array takes slightly longer to write since it must perform two writes, though it does not take a lot longer, since the writes are still done in parallel (Wong, 1995).

RAID 2 disk stripes at the bit level and uses parity information. Disk striping at the bit level means that the first disk holds the first bit of every byte, the second disk holds the second bit of every byte, etc. The last few disks hold the error correction code (the parity information). It takes advantage of Hamming codes, error correcting codes developed by R. W. Hamming in 1950 (Ferelli, 1994). Hamming error correction codes add three check bits to each group of four data bits. The check bits can then be used to correct one-bit errors automatically. Because all SCSI drives support built-in error detection (Trillium Research, Inc., 1994), RAID 2 is obsolete when using SCSI drives. Multiple check disks are required to figure out which disk failed and needs correcting, but only one is required to do the actual correcting (Chen, Lee, Gibson, Katz, & Patterson, 1993). Since disk controllers can now easily identify the failed disk, RAID 2 is no longer used very often. Unlike RAID 1, RAID 2 uses less then half of the disks as check disks, which reduces the percentage of the cost of the array that is being used to pay for check disks. RAID 2 can only handle one I/O transaction at a time, since every disk is involved in every transaction. This allows RAID 2 to handle very large data record sizes efficiently and for this reason it is mostly utilized in supercomputer environments.

RAID 3 disk stripes at the byte level and uses one disk per set for parity information. This type of striping writes the whole first byte on the first disk, the second byte on the second disk, and so on until it writes a byte on the second to last disk of the set. It then starts over at the first disk. The last disk is used for parity information. The parity information is based on the odd parity principle (Nixon, 1996) and can rebuild the data lost if one disk fails. If a second disk fails before the data from the second disk is rebuilt, data is lost. In odd parity, another bit is calculated from a group of bits (one from each disk). If there is an even number of bits assigned a value of one in the group, the parity bit is assigned a value of one. If there is an odd number of bits assigned a value of one in the group, the parity bit is assigned a value of zero. In this way, there will always be an odd number of ones in the group (if the parity bit is included). Therefore an error can be detected (if an even number of ones is counted) and when the disk that failed is identified, the error can be corrected or the data rebuilt (by calculating what value for the bit will give an odd number of ones for the group). Unlike RAID 1 and 2, RAID 3 only uses one disk for redundancy, therefore as the user adds more disks to the array, the percentage of money spent on redundancy will go down. This means a smaller percentage of the total cost of the array is used for redundancy in a RAID 3 setup than in either a RAID 1 or 2 setup. Also since data is striped at the byte level, all disks are involved in every read or write operation and only one I/O operation can be done at a time. This makes RAID 3 less effective in dealing with small numerous I/O transactions (such as databases), but very effective in dealing with a single large file (such as a multimedia file). RAID 3 is also slower on writes, because the parity must be recalculated.

RAID 4 disk stripes at the block level and uses one disk per set for parity information. Block striping allows the user to decide the size of the stripe. The size of the stripe is usually large enough to fit one whole file on a single disk. This allows small numerous reads to be processed simultaneously by reading each file from a different disk. The maximum number of files that can be read simultaneously is equal to the number of disks in the array. The downside is that every write must go through the parity disk. This creates a bottleneck and allows only one write at a time. RAID 4 is seldom implemented because of this bottleneck. If the same amount of disks is used, RAID 4 uses as small a percentage of the total cost for parity information as does RAID 3.

RAID 5 disk stripes at the block level and also stripes parity information. The main difference between RAID 4 and RAID 5 is that there is no dedicated parity disk in RAID 5. Instead each disk is separated into data and parity sections and parity is striped along with data. The parity information for one disk's information is divided between every other disk. This removes the bottleneck associated with multiple writes in RAID 4. RAID 5 can process multiple I/O transactions (both reads and writes), if the stripe size is set high enough. This makes RAID 5 much more effective in dealing with small numerous I/O transactions (such as databases) then either RAID 3 or 4 are. RAID 5 does not perform short writes very well, because, as in RAID 3 and 4, RAID 5 must perform four I/O transactions: read old parity and data, calculate new parity, and write new parity and data (Invincible Technologies Corporation, 1996). RAID 5 does have the best small read, large read, and large write performance of any of these five RAID setups, but because of the numerous I/O transactions required for writes, it cannot perform small writes better than RAID 1, which does not perform so many I/Os per write (Chen, Lee, Gibson, Katz, &

Patterson, 1993). RAID 5 can still perform large writes better, though, because when it begins to write it can divide the large write into small portions, which is something RAID 1 cannot. To compensate for the poor small write performance of RAID 5 arrays, many array vendors and users use write caching. A cache is a dedicated bank of high-speed memory where the data that is to be written can be written and later during idle machine cycles the data can be written to the array from the cache (Glossary of Computer Terms, 1996). There is a problem in using caches with arrays, though. If an error occurs in the cache, it will not be noticed by the array, which in turn threatens data integrity. Like RAID 3 and 4, RAID 5 can tolerate one disk crashing. RAID 5 uses as small a percentage of the total cost for redundancy as RAID 3 and 4 do.

The most commonly implemented levels of the original RAID levels are 1, 3, and 5. RAID 2 and 4 are hardly ever heard of anymore. RAID 1 is the easiest to setup and is commonly used when data availability and integrity are deemed as more important than the extra cost and lower performance associated with RAID 1. RAID 3 is commonly used when large single files, such as multimedia files, are the priority. RAID 5 is used when files such as databases, which need numerous small I/O transactions processed, are being used. It is now also common to see arrays that have the ability to switch between the different levels and even arrays that are partitioned so that part of it functions as one level and another part functions as another level.

Additional RAID levels have appeared since the original Berkeley papers were written. One, RAID 0, was described but not named in the papers. RAID 0 is really not RAID though, since it uses only disk striping and incorporates no redundancy (neither mirroring nor parity). This gives RAID 0 fast I/O transaction rates, but if even one disk goes bad all data on the whole array is made useless. The chance of a disk going bad increases as more disks are put on the array. Because of its inability to keep data safe for long periods of time, RAID 0 is normally only used when speed and performance are top priorities and data is only kept on the array for a few days or less. RAID 6 disk stripes at the block level and has two different sets of distributed parity instead of one. This makes it more resilient to disk failures than the other RAID levels. It can have up to two disks fail before data is lost. RAID 35 (or 53) is a combination of levels 3 and 5 (Baydel Ltd., 1996) and RAID 10 (or 0+1) is a combination of levels 1 and 0 (combining mirroring with striping). Levels 1 and 0 are combined by setting up two RAID 0 arrays and storing the same data on both (or in other words, mirroring one RAID 0 array with another). This combines the high performance of RAID 0 with the high data availability of RAID 1. It is just as expensive as RAID 1 though, because the array still needs twice the physical storage required by the user. RAID 10 can handle the failure of up to half of its disks (one side of the mirror) before losing data. Most of the other new levels are usually very much like existing levels and are invented just to trick consumers.

How does one acquire a RAID system?

There are two basic ways to acquire a RAID system: the user can either buy a ready-made RAID system or set one up himself or herself. Most people prefer to purchase a ready-made system. All the drives, adapter cards, and cables usually come in one enclosure. The easiest RAID levels for the user to assemble are RAID 0 (striping), RAID 1 (mirroring), and RAID 10(striping and mirroring), because they are the simplest in concept and design.

Whether the user is buying or assembling a RAID system, it is still important to decide which RAID level to use. All of the RAID levels have different degrees of cost, data availability and integrity, and performance. It is important to for the user to consider his or her own needs and decide which level is the best suited for toward those needs. If performance and cost are the only qualities that matter, RAID 0 would probably be the best choice. If data availability and integrity are the only qualities that matter, RAID 1 would probably be considered best. If the user needs a balanced mix of all of these qualities, then it would be best to venture into the higher levels (such as levels 10, 3, 5, and 6). Then it would come down to what types of files would the array be mostly working with and which level works best with those files.

If the user is going to buy a RAID system then there are still other options and choices. A user who is going to buy a RAID system can also buy an array that can run multiple levels of RAID, although this user still needs to decide which level the array should run. This user could also choose to buy an array that is separated into parts with each part using a different level. A certain part can be used to store files that require the qualities of the level it is running at. A user who has decided to buy an array should also look for a flexible array, one that can support multiple levels and be expanded and upgraded easily, in case his or her needs change.

The price for preconfigured RAID systems has fallen drastically over the past couple years. In 1992, one could buy a 4GB RAID system for about $25,600 (about $6.40 per MB) (Sullivan, 1996). In 1995, a 24GB RAID system could be bought for about $17,300 (about $0.72 per MB) (Sullivan, 1996), and the price continues to fall to this day. Right now, in 1996, 8GB arrays can be bought for anywhere from $6000 to $3000 (about $0.75 per MB to about $0.37 per MB) (Sauer, 1996). As the price falls, people at the entry level of the computer market, the most price-sensitive, are beginning to buy RAID systems. There are literally dozens of companies that sell RAID systems. The user must look around in order to find the one that offers the best price and the type of array needed.

As said before, the simplest levels to implement are levels 1 and 0, because of their simplicity. Though the user saves money by not buying it preconfigured, between $200 and $400 worth of software and cards, not to mention the actual disks that will be tied together to create the array, still need to be bought. One way to implement RAID in software is to plug in a controller card and another way is to hook up an external unit that appears to the computer as a SCSI device (Weiss, 1996). Some software can even be used to setup RAID 4 or 5. As said before though, most people prefer to buy a RAID system preconfigured.

What can RAID accomplish for AL/HRTD?

There are at least two projects that the Instructional Systems Research Branch (AL/HRTD) is working on which RAID could help with. The first is XAIDA (Experimental Advanced Instructional Design Associate), an ambitious exploratory research and development effort aimed at enabling relatively inexperienced instructional designers to plan and implement sophisticated interactive courseware (Smith, 1995). XAIDA uses transaction shells, reusable and programmable instructional strategy frameworks which contain instructional design expertise for selected learning objectives (Smith, 1995). Transaction shells are derived from transaction shell technology, which was developed by Dr. M. David Merrill and colleagues at Utah State University (Spector, Arnold, & Wilson, in press). Currently, XAIDA contains four transaction shells and supports the use of multimedia. The XAIDA templates store files in a database, allowing the program to "build" a lesson from separate files on-the-fly, as opposed to creating a single, large executable file. XAIDA currently runs on 486 PCs using the Windows 3.1 Operating System and uses standard Windows multimedia file format: bitmaps (.bmp) for graphics, wave (.wav) for audio, and (.avi) for animation or digital video. Since these separate multimedia files, which can range in size up to 12 MB each (e.g. in the case of digital video), are never actually combined into a single large file, it might be best to implement RAID 5, which works better with numerous small files, as opposed to RAID 3, which works better with single large files. RAID 35 (or 53), which, as you may recall, combines RAID 3 with RAID 5, might also work well with this type of program, because, although there are many numerous files to be worked with, these files are still rather large and only a few will be focused on at a time.

The second is TEEM (Training Efficiency and Effectiveness Methodology), a computerized, task-based training evaluation methodology that integrates training efficiency and effectiveness data to facilitate course revisions and improve training quality (Zukor, 1995). It consists of two distinct components: the Data Entry Component and the Presentation Component. For the Data Entry Component, TEEM uses large databases in order to hold the massive amount of data received from Occupational Survey Reports (OSRs), Course Plan of instruction (POI)/Training time (TT) information, effectiveness data, and transfer data (Instructional Systems Research Branch, 1996). The Presentation Component processes the information in the database and creates graphs and charts showing the results in easy to understand context. Because of RAID 5's ability to process many I/O transactions simultaneously without slowing down, it is ideally suited for working with large databases and programs (such as TEEM) which include large databases.

Because of their size, the amount of time it takes to write them, and their importance, both XAIDA and TEEM require high data integrity and availability. Both RAID 3 and 5 offer a fairly high amount of data availability, in that they can withstand the failure of one disk. If this failed disk is replaced and the data is rebuilt before a second disk can fail, no data will be lost. It is the same for data integrity. Both RAIDs can withstand the corruption of one disk, but not another before the first disk's set of data is recalculated. If an even higher degree of data availability and integrity is required, RAID 1 or 10 can, at the cost of an increased price and the loss of some performance, be implemented.

Conclusions

In this paper I have discussed the benefits of RAID technology, such as data availability and integrity and performance. I have outlined the capabilities of each of the basic levels of RAID (1-5), and identified how they can best be applied to suit the particular application. I have also described the more recently invented levels of RAID. Current programs that the Instructional Systems Research Branch is working with, XAIDA and TEEM, can take advantage of this technology and be greatly helped by the its benefits.

References

Baydel Ltd. (1996). "RAID Tutorial." http://www.baydel.com/tutorial.html.

Chen, P. M., Lee, E. K., Gibson, G. A., Katz, R. H., & Patterson, D. A. (1993). RAID: High-performance, reliable secondary storage (Tech. Rep. No. csd-93-778). Berkeley: University of California, Department of Electrical Engineering and Computer Sciences.

Ferelli, M. C. (1994, July). Disk array technology: Promise versus performance. Datapro computer Systems Analyst.

Glossary of Computer Terms. Computer Select, June 1996. CD-ROM database.

Instructional Systems Research Branch. (1996). Training Efficiency and Effectiveness Methodology (TEEM). Unpublished manuscript.

Invincible Technologies Corporation. (1996). "RAID Guide." http://www.invincible.com/rguide.html.

Nixon, R. (1996). "An Understandable Guide to RAID." http://www.nml.org/industry/allodyne/raidguide.html.

Patterson, D. A., Gibson, G. A., & Katz, R. H. (1987). A case for redundant arrays o inexpensive disks (RAID) (Tech. Rep. No. csd-87-391). Berkeley: University of California, Department of Electrical Engineering and Computer Sciences.

RAID Advisory Board. (1996). "About the RAB." http://www.raid-advisory.com/rab/about.rab.html.

Sauer, J. (1996, July 15).Arrays: Your data neverhad it so big. New Media, pp. 56-65.

Smith, A. (1995). The advanced instructional design advisor (AIDA). Unpublished manuscript.

Spector, J. M., Arnold, E. M., Jr., & Wilson, A. S. (in press). A Turing Test for Automatically Generated Instruction. Journal of Structural Learning.

Sullivan, K. B. (1996, May 6). Business RAIDs skyrocket. PCweek, pp. N3.

Trillium Research, Inc. (1994). "A Quick Explanation of RAID." http://www.adaptec.com/trillium/raid.html.

Weiss, J. (1996, February 19). RAIDing storage for multimedia. New Media, pp.34-38.

Wong, Brian. (1995, September). RAID: What does it mean to me? SunWorld Online. http://www.sun.com/sunworld online/swol-09-1995/swol-09-raid5.html#return1.

Zukor, K. (1995). Training Efficiency and Effectiveness Methodology (TEEM). Unpublished manuscript.

Note: All web addresses were correct as of July 1996. Some papers may have been moved since that time, though.

INSTRUCTION IN SCIENTIFIC INQUIRY SKILLS (ISIS)

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Final Report for:
High School Apprentice Program
Armstrong Laboratories

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INSTRUCTION IN SCIENTIFIC INQUIRY SKILLS (ISIS)

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Abstract

The *Instruction in Scientific Inquiry Skills* tutor (ISIS) is a computer program designed to teach students skills in scientific inquiry. During the 1995-96 school year, students used ISIS in conjunction with their standard science courses. Before and after the use of ISIS, tests were given to the students to measure their knowledge about science and the scientific inquiry skills. A correlation was found in comparing the scores of the ISIS users to those of the students that did not use ISIS. The users of ISIS outperformed the control students on 8 of the 9 skills.

INSTRUCTION IN SCIENTIFIC INQUIRY SKILLS (ISIS)

Jennifer M. Patterson

Introduction

The purpose of the FST intelligent tutors are to better the critical literacy skills in American students and workers. The goals of the USAF's Fundamental Skills Training (FST) project are to design, research, and transfer the intelligent tutoring systems (ITSs) to public schools, and, where appropriate to industry under federal technology transfer guidelines. FST currently has three of these tutors in the development and testing stages. The first tutor, the *Word Problem Solving* tutor (WPS), teaches students to analyze and solve mathematical word problems. *MAESTRO: The Writing Process* tutor, the second FST tutor, guides students through the many steps of constructing and writing a well-developed paper. The *Instruction in Scientific Inquiry Skills* tutor (ISIS) is the third of FST's tutors and is a simulation based intelligent tutoring system. The primary purpose of this tutor is to teach high school students scientific inquiry skills in the context of ecology and biology. ISIS teaches problem solving techniques, such as how to produce a question, generate a hypothesis, design an experiment, conduct the experiment, draw a conclusion based on the experiment, and to accept or reject their initial hypothesis. This tutor also teaches many ecological concepts and their relationships. ISIS is currently being implemented across the nation in 15 schools in New York, Pennsylvania, New Mexico, Ohio, and Texas.

Methodology

-Interface

ISIS is set up in a Medieval castle that is equipped with objects for the student's use and people to assist them. At any time during the tutor, the student can go to the library and use the "books" for researching their topic and the glossary to look up unknown words. They may also look at the map that is above their "desk" and view the different biomes. The student's desk also includes their "notebook," in which they can record information about what they have read and what they have learned from their experiments. Their desk has other useful tools, which will be mentioned later, that they will need to use during their experimentation. The student can check on the current status of their experiment by looking in their "toolbox." Their toolbox also holds the equipment they have chosen for their experiment. The student can also find assistance from Igor, their lab assistant, who helps the student through Scientific Inquiry and gives them feedback. Also, they can ask the wizard for advice and he will respond depending on the student's level of proficiency. The student receives points for doing tasks well, and can use these at the treasure chest, to "buy back" biomes that the Grim Reaper has stolen from the Earth. Each biome is divided into 25 squares and each square costs 50,000 points.

-Tour of the Biomes

The student "visits" the biomes by selecting a region on the world map. They view photographs of the flora and fauna that exist in the 9 biomes featured: Polar, Coniferous Forests, Marine, Grasslands, Freshwater, Rainforests, Deserts, Deciduous Forests, and Tundra. The Grim Reaper shows how the biomes of the world are being destroyed, and a wizard encourages the students to save the planet through their knowledge.

-Skill Instructional Modules (SIMs)

The student studies new skills through "books" in the library. They are taught how to generate questions and hypotheses through visuals, graphs, and text. Then the student learns how to design and conduct practical and useful experiments. The student also receives instructions on how to reach a conclusion from their experiment and to accept or reject their hypothesis. They earn up to 1,100,000 points for completing the SIM's.

-Domain Instructional Modules (DIMs)

The student is also able to read "chapters" about the specific biomes, abiotic factors of plant growth, biotic factors in an ecosystem, effects of human activities in nature, and ecology principles. These chapters include hotwords that they may select and "look up" in the glossary. Included in these chapters are pictures and diagrams which help to fully explain the information they have read. At the end of each page, the student is required to answer a question and they may earn a maximum of 1,000 points for each correct answer.

-Scientific Inquiry Tasks

The student first selects a question by choosing a "magic" mirror and using a concept map of the selected topic. Now they must generate a hypothesis with the crystal ball. If a hypothesis is generated properly, the student may earn 20,000 points. They choose the independent and dependent variable, and the units that address their hypothesis. The student now designs the experiment by going to the equipment room and choosing the proper equipment and putting it into their toolbox. Then they use the design experiment panel to setup the experiment by changing the values of their independent variable. The student may be awarded up to 35,000 points for correctly setting up an experiment. They go to the terrarium and run the experiment in a simulated biome and observe the changes in the biome and graph the results. For this, they may receive 50,000 points. The student generates a conclusion in almost the same manner in which they generated their hypothesis. Then they must accept or reject their hypothesis, depending on the conclusion they have just made. Doing this correctly can earn the student 65,000 points. Afterwards the student is prompted with a question related to the experiment they just conducted. They are to answer by "writing" their response in their notebook.

-Instructional Approach

ISIS teaches students the Scientific Inquiry Skills through a cognitive apprenticeship approach. The student is first given *models* of the skills in the SIMs. The modeling is demonstrated by an "expert" performing the skills that the student will soon need to use. Then the student is given *coaching* while using these new skills. ISIS can diagnose the student's problems and assist them where it is needed. Another element of this approach is *structuring and fading*. In the beginning, ISIS structures when a student will learn and use their skills. After the student achieves a high proficiency level, ISIS fades out and allows the student to choose when to use and review their skills. The final component is the student's *reflection* of their performances and their learnings from the experience. This helps the student to develop a better understanding of their scientific inquiry skills and basic knowledge of ecological concepts.

Results

At the 15 testing sites, 26 teachers in 83 sections of science were taught how to use ISIS. Approximately 2,000 students used ISIS from September of 1995, to May of 1996. Each student used the tutor for about 18 to 20 hours throughout the course of the school year. The students that used ISIS outperformed the control students on 8 of the 9 skill and knowledge subscales. The ISIS users gained about 8% from the pretest to the posttest, while the control group gained only about 3%.

Conclusion

The students that used the *Instruction in Scientific Inquiry Skills* tutor did in fact improve more than the control students. Their improvement throughout the year shows that ISIS works well with the traditional school curriculum, proving that ISIS is a beneficial learning tool.

FUEL IDENTIFICATION BASED ON NAPHTHALENE AND BENZENE DERIVATIVES

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FUEL IDENTIFICATION BASED ON NAPHTHALENE AND BENZENE DERIVATIVES

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Abstract

This study examined the gas chromatographic/mass spectral results of fuel samples to determine if fuels could be classified, even after weathering, according to peaks that corresponded to a series of naphthalene and benzene derivatives. The GC/MS results were used to train the computer using a 3-layer back-propagation neural network that would classify the fuel samples. After experimentation, the results showed that the naphthalene and benzene derivatives, excluding 1-ethylnaphthalene, were too volatile to withstand the weathering process. The mass of the compounds decreased to the point where the trained neural network could not identify with repeated accuracy the fuel classifications.

FUEL IDENTIFICATION BASED ON NAPHTHALENE AND BENZENE DERIVATIVES

Amanda Perrie

Introduction

Jet fuels are a necessary and significant part of the workings of the Air Force. Although jet fuels are used in numerous applications and have a number of benefits, there are also dangers present that might result from a spill. These include health risks, environmental pollution, and the risk of flammability. With a spill, legal problems also arise, including the questions of who will be responsible for the clean-up costs, legal fees, and fines. These legal questions have prompted the Air Force to formulate an objective and robust method for classifying fuels.

In the past, when a spill has been detected, the collected sample has been run through the GC/MS and the results were compared to the profiles of the different classifications of fuels to determine its type. This comparison was done visually and was thus a subjective determination. With this method, there also arose problems when the fuels were weathered due to the decrease in different components of the fuels.

A more objective method that could be used to classify fuel types is one that uses pattern recognition and neural networks to train a computer to decide a fuel type. Patterns could be developed that avoid the overall changes in the GC results due to contamination, analytical errors, and weathering of the fuel samples. Various pattern recognition methods have been proposed and tested for the classification of jet fuels[2,9]. Artificial neural networks are a promising new pattern recognition technique which has been successfully applied to the classification of jet fuel profiles[6,8].

Artificial neural networks (ANNs) are computer simulations of biological nervous systems[10]. A schematic representation of an ANN is displayed in Figure 1. In general terms, numerical information enters a network through a layer of input neurons or nodes and exits through a layer of output nodes. Information passes from the input to the output layer through a hidden layer (or layers). As information is passed through the layers, numerical weights, biases and transfer functions are applied that adjust the connection between the nodes. Wythoff has written a tutorial on back-propagation neural networks[11].

A recent review of pattern recognition techniques by Brown, *et al* [12] noted "The most novel research in pattern recognition involved work with artificial neural networks." There are at least three steps in the application of neural networks to classification problems such as this one: training, architecture optimization, and validation.

Training is the automated process of adjusting the weights and biases in the network so that the output patterns generated by the network match those in the training data set. This process is interconnected with architecture optimization, which is the process of determining the number of input, hidden and output nodes required in the ANN to yield the most accurate classification results. Training and architecture optimization continue until an architecture is found that properly classifies the samples in the training set and has a minimum size. Validation is the process of showing that the trained network correctly classifies patterns not used in the training process.

The choice of chemical compounds to use in forming the data patterns for ANN analysis is of considerable importance. Jet fuels contain hundreds of chemical components, and typical capillary gas chromatographic separations of these fuels yield between 150 and 250 peaks which represent single compounds or small groups of highly similar compounds which cannot be separated[14,15]. Peak area measurements can be obtained from peaks occurring throughout a fuel's chromatogram and used to form a pattern for pattern recognition analysis. However, it may be more efficient to concentrate efforts on a restricted set of compounds which can be separated and quantified by gas chromatography or gas chromatography/mass spectrometry. Mayfield and Henley have performed classification experiments on jet fuels and arrived at a set of benzene derivatives as potential "marker" compounds for use in classifying jet fuels. These compounds were: benzene, isopropylbenzene, 1,2-diethylbenzene, 1,2,3,4-tetramethylbenzene, 1,2,3,4-tetrahydronaphthalene, and 1-methylnaphthalene[9].

Spilled fuels undergo chemical changes after entering the environment, and these changes are collectively called "weathering". The most rapid weathering process is usually evaporation, which results in the loss of components from a fuel spill in order of volatility, with the most volatile components being lost or reduced in concentration before the less volatile components. Other weathering mechanisms include oxidation, dissolution of water-soluble components, and microbial degradation. Douglas, *et al.* studied the identification of weathered crude oils and heavy refined oils and concluded that polynuclear aromatic hydrocarbons (PAHs) and their alkylated derivatives were promising marker compounds for the identification of such heavy oils. Further, because some PAH compounds have been found to be more biodegradable than their alkyl-derivatives, the alkyl-PAH compounds were recommended as fuel identification markers.[3,4,7] Applying Douglas' advice to jet fuels requires knowledge of what PAHs are present in jet fuels. Of the various PAH compounds found in heavier fuels, jet fuels contain easily detectable concentrations only of naphthalene and some naphthalene derivatives[14,15].

The goal of this study was to form a pattern based on the naphthalene and benzene derivatives found in the GC results. This pattern could then be used in a 3-layer back-propagation neural network to classify weathered and un-weathered fuels according to their types.

Methodology

The method used to determine the composition and the concentration of compounds in the fuel samples was gas chromatography/ mass spectrometry (GC/MS). Gas chromatography, defined by H.M. McNair and E.J. Bonelli in Basic Gas Chromatography, is the separation and distribution of a sample in two phases, (1) a stationary bed of large surface area and (2) a gas which flows through the stationary bed. Volatile substances are separated as the gas stream moves over the stationary phase. Gas chromatography is frequently used in experiments to determine the fuel's components[2,5,6,7]. This experiment used a form of gas chromatography known as capillary gas-liquid chromatography (GLC). In GLC, the stationary phase is a thin liquid film spread over a solid support or on the walls of the separating column. In the capillary form of GLC, the column is fashioned from a length of capillary tubing, and the liquid stationary phase is coated on the walls of the column . The partitioning of the sample in and out of this liquid film was the basis for separation.

Data Collection Conditions:

The samples were analyzed by gas chromatography/mass spectrometry, utilizing an instrument calibration method designed to provide accurate quantitative measurements of the sample concentrations of the selected benzene and naphthalene derivatives. Before injection, the samples were diluted with methylene chloride and spiked with two internal standards: d_{10}-ethylbenzene and d_{10}-anthracene. Quantitation was based on the d_{10}-anthracene, and the d_{10}-ethylbenzene provided a quality control measurement, being used along with the d_{10}-anthracene to quickly reveal analysis runs which had failed due to instrumental accident or artifact.

The samples were analyzed using a benchtop gas chromatograph/mass selective detector system (HP-5890 GC and HP-5970 MSD). The gas chromatograph and mass selective detector were interfaced by a direct capillary inlet. The gas chromatograph was equipped with a split/splitless injection port for use with capillary columns and was modified to an HP-5890 series II configuration, with electronic pressure control. A personal computer (HP

Vectra 486/66mhz) running HP DOS/Windows MS-Chemstation Software was used for system control and data acquisition. Injections of prepared samples were made with a HP-7673A autosampler.

Gas chromatographic separations were made using a fused silica capillary column, 20m long, with an internal diameter of 0.1mm, and coated with 0.4mm of bonded and crosslinked polymethylsiloxane with 5%-phenyl substitution (DB-5, J&W Scientific, Inc.). Helium carrier gas was supplied with a constant head pressure of 45 psig. The temperature program conditions are listed in Table 1. The capillary column was plumbed directly to the ion source of the mass selective detector using a direct capillary interface. Injections were made with the autosampler, and with the injection port operated in the split mode.

The mass selective detector was a quadrupole mass spectrometer with an electron impact ion source. The MSD was scanned from 35 amu to 500 amu using mass spectral conditions summarized in Table 2. Selected analytes were quantified using the EnviroQuant target analyte software provided by the Chemstation computer, and using target ions and retention times established for the selected analytes by the analysis of standard mixtures.

Table 1. Gas Chromatography Conditions

Initial Oven Hold:	4 min.
Oven Program Rate:	15°C/min.
Final Oven Temp.:	270°C
Final Oven Hold:	5 min.
Injection Port Temp.:	300°C
MS Interface Temp.:	225°C
Carrier Gas:	He
Head Pressure:	45 psig
Injection Volume:	1 μL
Split Port Flow:	60 mL/min.

Table 2. Mass Spectrometry Conditions

Solvent Delay:	4 min.
Electron Multiplier:	1800 volts
Ionization Method	Electron Impact
Ionization Voltage:	70 volts
Low Mass:	35 amu
High Mass:	500 amu
A/D Duplicate Samples:	4 samples/axis point
Scanning Rate:	1.3 scans/sec.

105 fuel samples representing a variety of fuels including JP-4, JP-5, JP-7, JP-8, JPTS, Avgas, and Jet A were collected from Wright Patterson AFB Energy Management Laboratory, Mukilteo WA Energy Management Laboratory, MacDill AFB, and Wright Patterson Aerospace Fuel Laboratory. (See Table 3)

Table 3. Jet Fuel Training Set

Number of Samples	Fuel-Type
20	JP-4 (fuel used by USAF fighters)
13	JP-5 (fuel used by navy jets)
8	JP-7 (Fuel used by the USAF SR-71 reconnaissance plane)
20	JP-8 (fuel used by USAF fighters)
11	JPTS (fuel used by the USAF TR-1 and U-2 aircraft)
20	Jet A (fuel used by civilian airliners)
13	AVGAS (100/130 octane aviation gas)

A sample was made from each fuel and then run through the GC/MS. The sample consisted of 100 µL of the fuel, 100 µL of the Internal Standard Solution, and 800 µL of methylene chloride. The Internal Standard Solution consisted of 25 mg d_{10}-anthracene and 25 µL d_{10}-ethylbenzene made to a volume of 25 mL with methylene chloride. The GC results were then quantitated twice. Once with a set of two standards of naphthalene derivatives (compositions found in tables 4. and5.) and once with a standard of naphthalene and benzene derivatives combined (composition found in table 6).

Table 4. Standard 1: PAH in Fuel Standard Preparations

Solvent:	Methylene Chloride
Volume (mL):	25

Compound	Mass (µg)	Conc.(µg/mL)
naphthalene	50	2
1-methylnaphthalene	50	2
2-methylnaphthalene	50	2
1,2-dimethylnaphthalene	50	2
1,3-dimethylnaphthalene	50	2
1,4-dimethylnaphthalene	50	2
1,5-dimethylnaphthalene	50	2
1,8-dimethylnaphthalene	50	2
2,3-dimethylnaphthalene	50	2
2,6-dimethylnaphthalene	50	2
1-ethylnaphthalene	50	2
2-ethylnaphthalene	50	2
1,4,6,7-tetramethylnaphthalene	50	2

Table 5. Standard 2: PAH Single Component Compounds

Solvent:	Methylene Chloride
Volume (mL):	25.00

Compounds	Volume (µL)	Density (g/mL)	Mass (mg)	Concentration (mg/mL)
Naphthalene			49.9043	1.996
1,4-Dimethylnaphthalene	50.0	1.0166	50.83	2.033
2,3-Dimethylnaphthalene			49.9716	1.999

Table 6. Benzene and Naphthalene Standard

Solvent:	Methylene Chloride			
Volume (mL)			25.00	
Compound	Volume (µL)	Density (g/mL)	Weight (mg)	Conc. (mg/mL)
benzene	100	0.87865	87.87	3.51
Isopropylbenzene	100	0.8618	86.18	3.45
1,2-diethylbenzene	100	0.88	88.00	3.52
1,2,3,4-tetrahydronaphthalene	100	0.9702	97.02	3.88
1-methylnaphthalene	100	1.0202	102.02	4.08
1-ethylnaphthalene	100	1.00816	100.82	4.03
1,2,3,4-tetramethlybenzene	100	0.9052	90.52	3.62
2,6-dimethylnaphthalene			50.00	2.00
2,3-dimethylnaphthalene			50.02	2.00

Once the fuels were quantitated using these three standards, the data was fed as a pattern into a fuel identification program to use as a training set. This set of fuels was broken down into four training sets with four prediction sets and tested.

The next step was to set up a series of fuels to be weathered and then run through the GC to later be used as a prediction set in the neural network. Twenty-six vials (two for each fuel sample) were set up underneath the hood to allow the weathering process to occur. The first vial was used to track the mass of the fuel, while the second vial was used to extract samples to be run in the GC. The 13 fuels used can be found in Table 7.

Table 7. Fuel Samples in Weathering Experiment

Sample Number	Fuel Type	Sample Information
1	JP-4	Fuel B+1 #1
2	JP-8	Sample #89-70
3	JP-5	HF012 MacDill
4	Jet A	448 HF152
5	JPTS	#10 HF057
6	JP-4	Tyndall 15 July 1993
7	JP-8	94-F-2030
8	Jet A	HF163
9	JP-4	HF115
10	JP-8	94-F-2317
11	Jet A	87-F-468 HF154
12	JPTS	94-S-2013
13	JPTS	94-S-2013

Each day a sample was made for each fuel from vial number 2. The sample consisted of 100 μL of the fuel, 100 μL of the Internal Standard Solution (the same as above), and 800 μL of methylene chloride. The mass loss was monitored daily by recording the weight of vial number 1 for each sample.

Results

The gas chromatographic conditions used yielded jet fuel separations in less than 25 minutes. The naphthalene compounds studied initially could be separated into 12 peaks, one of which represented two co-eluting compounds, 1,4-dimethylnaphthalene and 2,3-dimethylnaphthalene. The total ion chromatogram of a typical JP-4 sample is shown in Figure 1. Most of the naphthalene derivatives co-eluted with saturated hydrocarbons from the fuel, due to the chemical complexity of the fuel. However, it was possible to isolate the responses from the naphthalene derivatives by using selected ion profiling. The naphthalene derivatives calibrated by Standard 1 could be quantified using the retention times and quantitation-ions listed in Table 9. A total of 102 chromatograms were obtained from the stock of preserved fuel samples. The entire collection could be used to train ANNs and other pattern recognition classification systems, or a portion of the data could be used for training, with part of the data split off as simulated unknowns in an evaluation set. No ANN composed of data from the entire data set of naphthalene derivatives proved capable of classifying the data set without error.

Table 8. Naphthalene Derivative Results

Compound	Retention Time (min.)	Quantitation Ion (amu)
d10-anthracene (internal standard)	21.70	188
1,2,3,4-tetrahydronaphthalene	14.90	104
naphthalene	15.22	128
2-methylnaphthalene	16.49	142
1-methylnaphthalene	16.70	142
2-ethylnaphthalene	17.52	141
1-ethylnaphthalene	17.58	141
2,6-dimethylnaphthalene	17.63	156
1,3-dimethylnaphthalene	17.81	156
2,3- & 1,4-dimethylnaphthalene	18.03	141
1,2-dimethylnaphthalene	18.21	141
1,8-dimethylnaphthalene	18.43	156
1,4,6,7-tetramethylnaphthalene	20.35	184

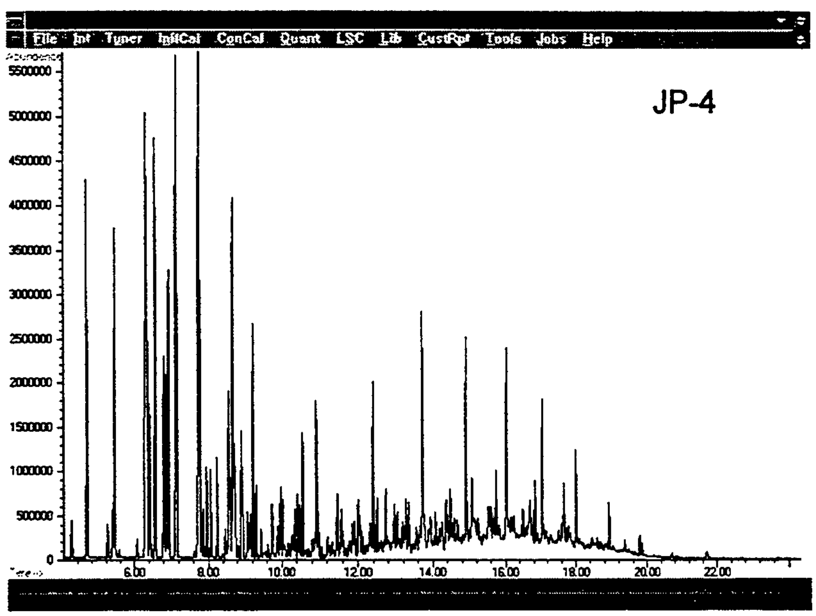

Figure 1. Total Ion Chromatogram of a typical JP-4 sample.

When the quantitation scheme was extended to include some benzene derivatives, as were included in quantitation Standard 3, more concrete results were obtained. Feature selection based on Fisher weights plus the removal of highly correlated features yielded six features which could serve to train an ANN which could successfully classify the training set of data from fresh fuels. The fresh fuels could be classified using a 3-layer ANN trained by back-propagation and consisting of six inputs, six hidden nodes, and six outputs used for a total of 84 variables. A diagram of this can be seen in Figure 2. The The compounds used as input nodes and the jet fuel classes used as output nodes are listed in Table 9. Table 9 also gives the retention times and quantitation ions used for the six input node compounds. The input node data consisted of the compound concentrations in mg/mL in the prepared fuel sample (Which in turn were 1/10 the concentrations in the original fuel sample due to the sample dilution).

Table 9. Three-Layer Back-Propagation ANN

Inputs	Retention Time (min.)	Quantitation Ion (amu)	Outputs
isopropylbenzene	11.46	105	JP-4
1,2-diethylbenzene	13.45	119	JP-5
1,2,3,4-tetramethylbenzene	14.68	119	JP-7
1,2,3,4-tetrahydronaphthalene	14.89	104	JP-8
1-ethylnaphthalene	17.58	141	JPTS
2,3- & 1,4-dimethylnaphthalene	18.02	141	Jet A

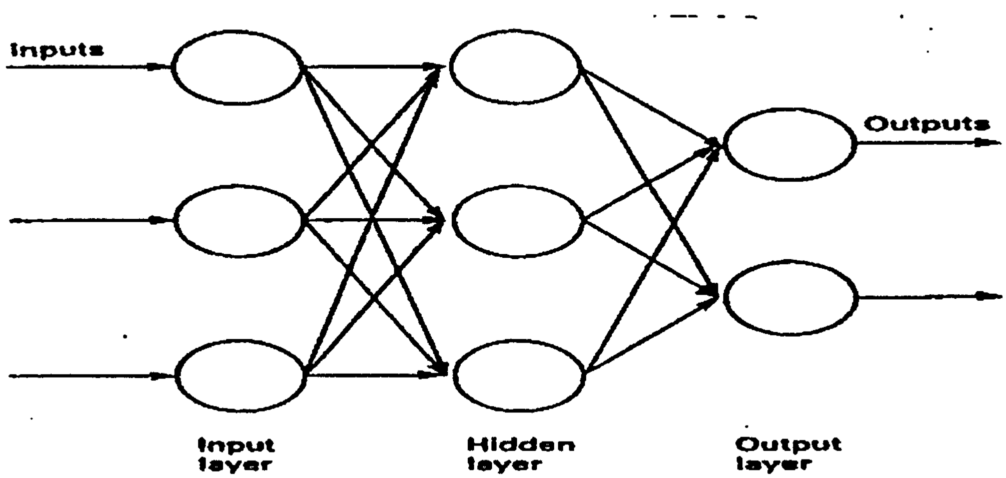

Figure 2. Generic ANN trained by Back-Propagation

The neural network classification process was broken down into two s and JP-8 fuels together. The second step classified the two separate fue architecture, the fuel samples were broken down into training sets and pr subsets can be seen in Tables 10. and 11. The results of the predictions predicting the fuel types with a greater than 90 percent accuracy. (see T

Table 10. Step 1 Composition

Composition of Training and Prediction Subsets		
Category	No. in Training	No. in Prediction
JP-4	18	2
JP-5	11	1
JP-7	7	1
JP-8 and Jet A	36	4
JPTS	9	1
AVGAS	11	1
TOTAL	92	10

Table 11. Step 2 Composition

Composition of Training and Prediction Subsets		
Category	No. in Training	No. in Prediction
JP-8	18	2
Jet A	18	2
TOTAL	36	4

Table 12. Subset Results

	Training No. Correct		Prediction No. Correct	
TSET/PSET Pair No.	Step 1	Step 2	Step 1	Step 2
	out of 92	out of 36	out of 10	out of 4
1	92	36	9	4
2	92	36	10	2
3	92	36	9	4
4	92	36	10	3

The 13 fuel samples set up for the weathering process were weathered for a period of two weeks. The masses decreased, especially those of the JP-4 and one of the JP-8 fuels (which has many of the characteristics of a JP-4 and may be misclassified). The fractional mass losses for the fuels can be seen in Figure 3.

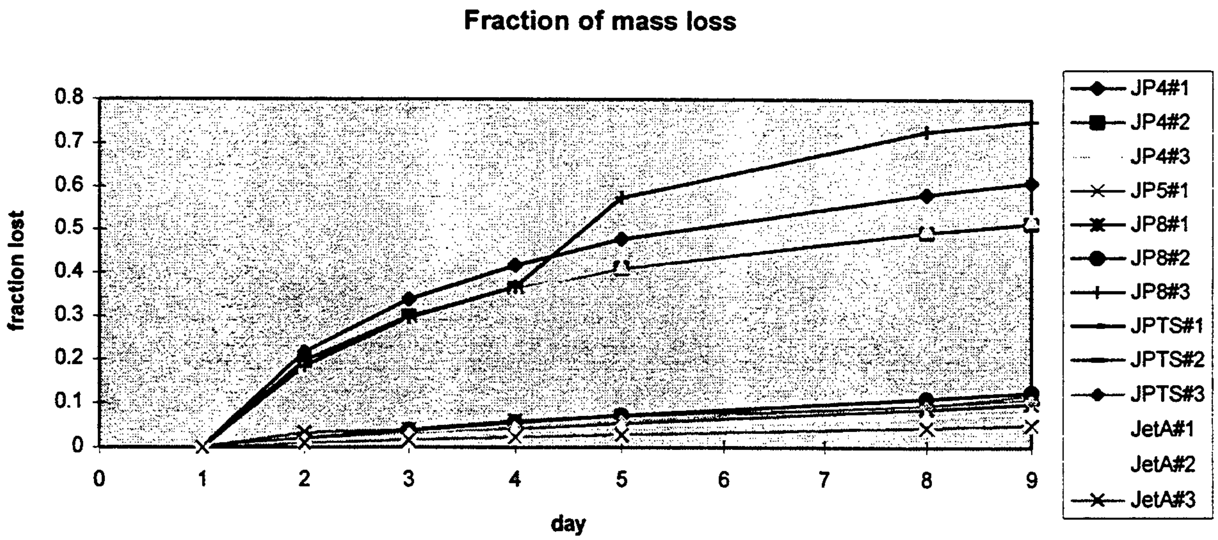

Figure 3. Fractional Mass Loss from fuels due to weathering.

The weathered fuel samples were run through the GC/MS to obtain the quantitation results. These results were then fed into the FIP program to be used as a prediction set. The fuels were not classified with a high degree of accuracy due to the volatility of the benzene and naphthalene compounds.

Conclusions and Recommendations

The all naphthalene standard did not classify the fuel types correctly using a one step 3-Layer Back-propagation neural network. However, it should be tested using a two step process as was done with the combined naphthalene and benzene derivative standard.

The standard containing both naphthalene and benzene derivatives classified the un-weathered fuels with a 90-100 percent accuracy, but could not correctly classify the weathered fuel samples. Further studies should be done to find compounds that can be identified using the GC/MS, are indicative of a certain fuel type, and can withstand the weathering process.

References

1. McNair, H. M., and Bonelli, E. J., *Basic Gas Chromatography*, Consolidated Printers, California, 5th edn., 1969, pp. 1.

2. Lavine, B. K., Stine, A., and Mayfield, H. T., *Analytica Chimica Acta*, 277 ,1993, 357-367.

3. Douglas, G.S.., and Uhler, A.D.., *Environmental Testing and Analysis*, 2 (3), 1993, pp. 46-53.

4. Douglas, G.S., Bence, A. E., Prince, R.C., McMillan, S. J., and Butler, E. L., *Environ. Sci. Technol.* 30, 1996, 2332-2339.

5. Zemo, D. A, Bruya, J. E., andGraf, T. E., *Ground Water Monitoring & Remediation*, Spring 1995, pp. 147-156.

6. Long, J. R., Mayfield, H. T., Henley, M. V., and Kromann, P. R., *Analytical Chemistry*, 63(13), 1991, 1256-1251.

7. Prince, R. C., Elmendorf, D. L., Lute, J. R., Hsu, C. S., Halth, C. Esenius, J. D., Dechert, G. J., Douglas, G. S., and Butler, E. L., *Environ. Sci. Technol.*, 28, 1994, 142-145.

8. Lavine, B. K., Mayfield, H.,Kromann, P. R., and Farque, A., *Analytical Chemistry*, 67, 1995, 3846-3852.

9. Mayfield, H. T. and Henley, M. V., "Classification of Jet Fuels using High Resolution Gas Chromatography and Pattern Recognition", *Monitoring Water in the 1990's: Meeting New Challenges, ASTM STP 1102*, Hall, J. R. and Glysson, G. D., eds, American Society for Testing and Materials, Philadelphia, 1991, pp. 578-597.

10. *Neural Network TOOLBOX: For Use with MATLAB™*, The Mathworks, Inc. Natick Massachusetts, 1992.

11. Wythoff, B.J. , *Chemom. Intell. Lab Syst.,* 18, 1993, 115-155.

12. Brown, S.D., Blank, T.B., Sum S.T., Weyer, L.G., *Analytical Chemistry*, 66, 1994, 315R-359R.

13. Andrews, J.M.; Lieberman, S.H., *Analytica Chimica Acta*, 285, 1994, 237-246.

14. Hughes, B. M., Wiefling, K., and Adams, G., Variability of Major Organic Components in Aircraft Fuels, USAF Report ESL-TR-85-13, Tyndall AFB, FL, December 1984, Unclassified (Available through DTIC).

15. Mayfield, H. T., JP-8 Composition and Variability, USAF Report AL/EQ-TR-1996-0006, Tyndall AFB, FL, May 1996, Unclassified (Available through DTIC).

A STUDY OF THE VERTICAL SHIFTS IN SCENE PERCEPTION MEMORY

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A STUDY OF THE VERTICAL SHIFTS IN SCENE PERCEPTION MEMORY

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Abstract

Two sets of scene photos, close-ups and wide angles, were analyzed for vertical shifts in the scene perception memory of the people who drew them. The original photos were those used by Intraub and Richardson (1989). In that study students examined each picture for 15 seconds and were told to redraw the pictures exactly as they remembered them. For my research, I identified common points between the originals and the drawings that the subjects had created. I then measured the vertical position of each point with respect to the middle of each picture. I did this for both the close-ups and the wide angles. I then compared each of the drawings to the originals. I found that, generally, the subjects contracted the objects in the pictures they drew and also had a greater tendency to shift objects in their scene perception memory downwards rather than upwards.

A STUDY OF THE VERTICAL SHIFTS IN SCENE PERCEPTION MEMORY

Esther I. Resendiz

Introduction

Intraub and Richardson (1989) did research in which their subjects (undergraduate students in a psychology class) redrew from memory pictures which they had previously viewed for 15 seconds each. The results of Intraub and Richardson's study revealed that people tend to extend the boundaries of remembered scenes (See Figure 1). Casual analysis of their subject's drawings reveals a recurring phenomenon in which the objects in the scenes have a tendency to be contracted, as if being viewed from a further distance, and drawn lower in the visual field than was originally viewed by the subjects. This also helps to support Previc's (1990) theory about scene perception memory. His theory basically states that most of the objects which are close to us occur in the lower visual field and objects which are far away generally occur in the upper visual field. This might explain why most of the objects were contracted and shifted vertically lower. According to Previc's theory, perhaps this contraction and shift can be explained by a subject's memory pushing an image further away, thus, expanding the upper field extent, which pushes the original image lower. The extent of vertical shifts that occurred in the subject's drawings were carefully examined. This is an important phenomenon that requires further research because we must understand the discrepancies between what people see and what people think they saw. Since spatial disorientation is partly a result of visual illusions, the phenomenon of vertical shifts in scene perception memory is extremely relevant towards understanding spatial disorientation.

Methodology

Intraub and Richardson prepared two versions of 20 scenes, one in which the main objects were slightly cropped (close-up) and one in which they were not (wide angle). Eighty-five subjects were presented with the same 20 scenes for 15 seconds each. Half of the scenes were shown in their cropped version and half were shown in their slightly wider-angle uncropped version. Across subjects, scenes were presented in each version equally often. The subjects were instructed to remember each picture in as much detail as possible and to consider the background as important as the foreground. After 48 hours, subjects were asked to draw up to six of the pictures. Each of the pictures was to be drawn within a 4" by 6" rectangle. They were told to consider the edges of the rectangle to be the edges of the photograph and to draw the pictures accordingly (Intraub & Richardson, 1989). The slides were developed into pictures and copied for easier examination. The drawings which the subjects had produced were also copied for easier examination. A total of 84 close-up pictures and 126 wide angle pictures were analyzed. Then, common points in the original and in the subsequent drawings were noted and marked. A point was chosen if it was clearly visible in the original and in the majority of the drawings. (See Appendix for specific points.) The midpoints in the drawings and in the originals were marked as point "0." The vertical position of the common points were then measured by drawing a horizontal line through the common point to both of the vertical edges. Then, the lines drawn through the left vertical edge were measured in centimeters with relation to the midpoint using a "+" sign for points above the midline and a "-" sign for points below the midline. The numbers were then converted to percents to make the originals comparable to the drawings, which were considerably smaller. The percents ranged from +01 through +100 and -01 through -100. A total of 31 points from the original set of close up pictures were measured. A total of 54 points from the original set of wide angle pictures were measured. The points were entered into a computer for a thorough analysis of the vertical shifts in the drawings.

Results

Analysis on the computer revealed a definite downward vertical shift in the majority of the drawings, both close-ups and wide angles.

Close-Ups - Based on an average of all points in a figure, 67.9% (57 out of 84) of all drawings showed a downward shift. There were 90 total upper visual field points and 47 total lower visual field points. One would expect for the upper visual field points to make a downward shift if a contraction of the image was truly the only phenomenon occurring. As can be expected, 82.2% of the upper visual field points shifted downwards whereas only 17.8% of the points shifted upwards. A similar result should have been expected of the lower visual field points. However, only 68.1% of the lower visual field points shifted upwards. Contrary to the results that would have been expected in the contraction theory, 31.9% of the lower visual field points shifted even lower (See Figure 2). Based on these results, one can be able to see that there might be more than just the contraction of images taking place. An overall downward shift is strongly implicated. The average original point of the upper visual points was +23.8%, whereas the average original point of the lower visual field points was -46.6%. With these statistics, one would expect for the lower visual field points to experience the greatest shifts since they originated so far away from the midline. This was not the case. The lower visual field points had a shift of only +12.8% and the upper visual field points had a shift of -28.9%. That is approximately a 1:2 ratio, meaning that, on average, for every one centimeter that a lower field point was moved up an upper field point was moved down roughly two centimeters.

Wide Angles - Based on an average of all points in a figure, 63.5% (80 out of 126) of all drawings showed a downward shift. There were 192 total upper visual field points and 143 total lower visual field points. As can be expected with a contraction, 85.0% of the upper visual field points shifted down and only 15.0% of the same points shifted up. However, only 68.5% of the lower visual field points shifted up and 31.5% of the same points shifted down (See Figure 3). This is indicative of an additional phenomenon of vertical shift beyond the image contraction. Also, the average original position of the upper visual field points was +24.6% and the average original position of the lower visual field points was -31.3%. One would expect that the shift in the lower visual points would be greater since their position was further away from the midline. However, the lower visual field points had a shift of only +19.6% whereas the upper visual field had a shift of -31.2%. That is approximately a 1:1.5 ratio, meaning that, on average, for every one centimeter that a lower field point was moved up, an upper field point was moved down 1.5 centimeters.

Discussion

Based on an average of all the points in a figure, 65.2 % (137 out of 210) of the drawings showed an overall downward shift. When it came to measuring just how much of a shift was made, the close-up drawings revealed a 2:1 ratio of upper point downward shifts to lower point upward shifts while there was only around a 1.5:1 ratio of upper point downward shifts to lower point upward shifts in the wide angles. In almost all of the pictures, in addition to a vertical shift, there was also a contraction of the image.

What causes the image to contract and shift down when drawn from memory? It has been argued before that the reason the images are contracted is so that the cropped objects (in the case of the close-up pictures) can be completed. The fact that even in the wide angle pictures (in which the entire object is complete) there is still a contraction of the image and a vertical shift downwards disproves this theory. Thus, one can conclude that that the contraction observed could be caused by the subjects perceiving the objects as being further away. However, it can be noted that the amount of downward vertical shift is lessened in the wide angle pictures. This brings about an interesting question. Is there a point where the image stops contracting and vertically shifting downwards? Is there a distance from which a picture can be taken where if a similar experiment to the one I studied was conducted the results would yield no noteworthy contraction or vertical shift? Further research needs to be done in this area because we need to understand some of the most basic questions concerning why people see and remember things the way they do.

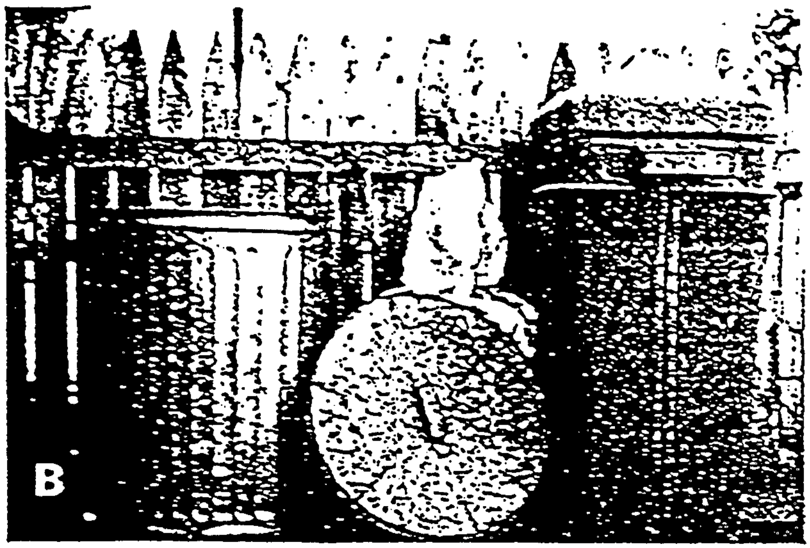
The purpose of my study was to study the vertical shifts in scene perception memory. Though our sample group only consisted of only 210 pictures, we definitely observed a phenomenon of downward vertical shifts.

References

Intraub, H., & Richardson, M. (1989). Wide-Angle Memories of Close-Up Scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 2,* 179 - 187.

Previc, F.H. (1990). Functional Specialization in the lower and upper visual fields in humans: Its ecological origins and neurophysiological implications. *Behavioral and Brain Sciences, 13,* 519 - 575.

FIGURE 1



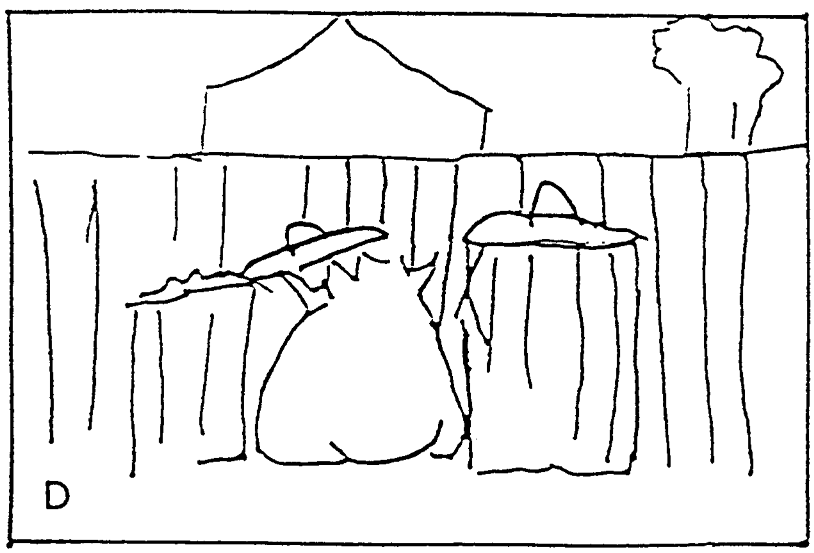


FIGURE 2

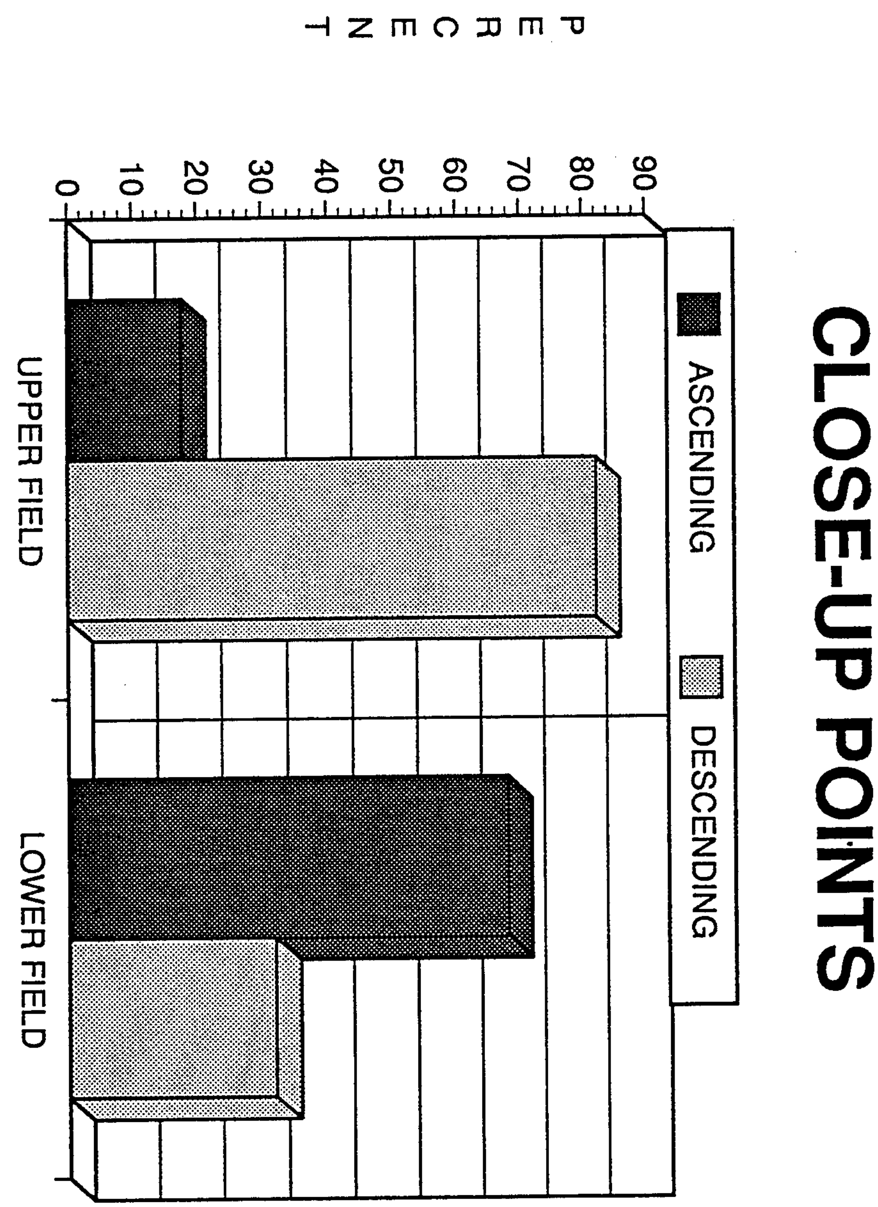
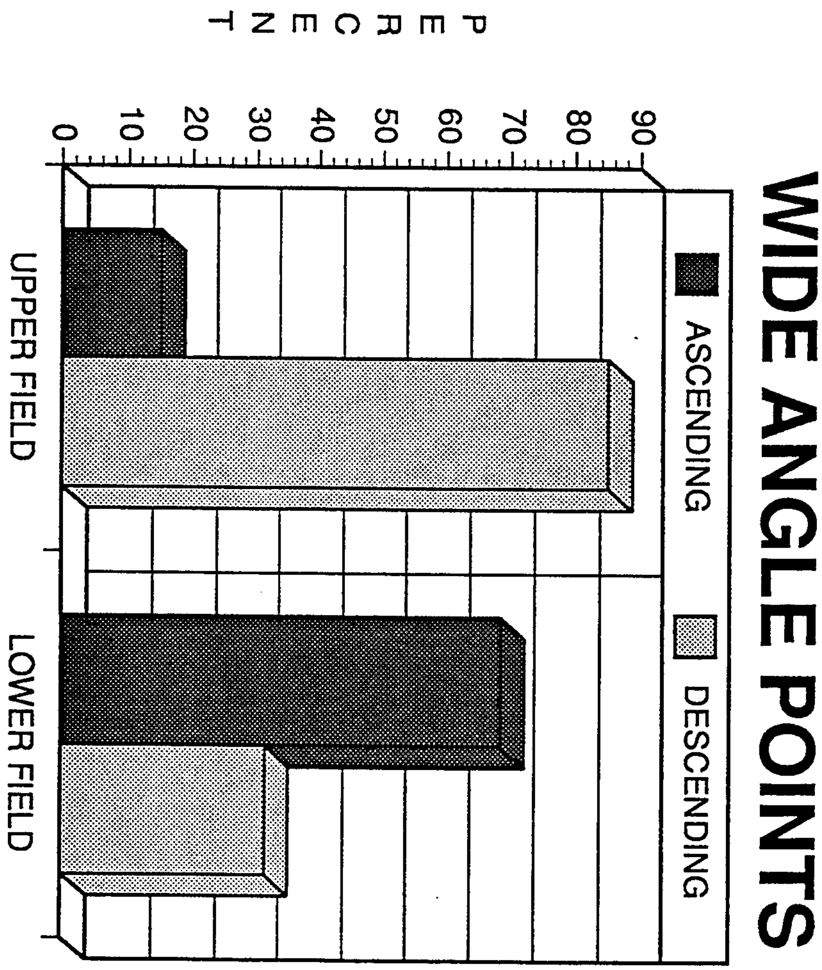

CLOSE-UP POINTS
ASCENDING
DESCENDING
PERCENT
0
10
20
30
40
50
60
70
80
90
UPPER FIELD
LOWER FIELD

FIGURE 3


WIDE ANGLE POINTS
ASCENDING
DESCENDING
PERCENT
0
10
20
30
40
50
60
70
80
90
UPPER FIELD
LOWER FIELD

Appendix

Close Ups

*Trashcans

1. Closest top edge of the smallest trash can

*Globe

2. Horizontal line across the middle of the globe
3. Lowest point of globe

*Beer

4. Closest top corner or the top right hand corner if no perspective is shown

*Shoes

5. Highest point on the higher sneaker (or of the one sneaker)
6. Highest point on the lower sneaker
7. Lowest point on the higher sneaker (or of the one sneaker)
8. Lowest point on the lower sneaker

*Pizza

9. Highest point on the crust (except if image is completely inverted)

*Lawnmower

10. Highest point of the lawnmower engine

*Horn

11. Highest point on the mouthpiece

*Candle

12. Highest point on the candlestick holder

*Car

13. Highest point of the roof of the car
14. Midway point of the bottom of the front window
15. Lowest point of the car midway between the two front tires

*Woman

16. Middle of her sunglasses
17. Bottom of her chin
18. Lowest point on the book

*Blender

19. Highest inside bottom point of handle
20. Highest midway point of the base

*Fruit

21. Middle of the label (Dole)

*Door

22. Middle of the door handle
23. Middle of the botom part of the door

*Fan

24. Middle of the inside metal part of the fan
25. Bottom of the metal part of the fan

*Television

26. Upper right corner of the TV
27. Lower right inside corner of the screen

*Lamp

28. Lowest front middle point of the lamp shade
29. Middle point of the side of the table further in the distance

*Phone

30. Midway point of the bottom of the receiver handle
31. Midpoint of the top side of the middle button in the bottom row of numbers

Appendix

Wide Angles

*Trashcans

1. Highest point of the fence (left most point on the main fence not included)
2. Top of the handle of the lid on the largest trashcan or if there is no handle then the top of the lid or if there is no lid then the highest point of the large, plastic garbage can
3. Bottom most part of the front top edge of the small, metal garbage can
4. Highest point of the lid on the ground

*Globe

5. Highest point on the globe
6. Midpoint of the lowest edge of the bookshelf
7. Lowest point of the globe
8. Lowest point of the globe stand

*Beer

9. Highest point on the single beer
10. Closest top corner or the top right hand corner if no perspective is shown
11. Closest bottom corner or the bottom right hand corner if no perspective is shown
12. Lowest point of the single beer

*Shoes

13. Highest point of the higher sneaker (or of the one sneaker)
14. Highest point of the lower sneaker
15. Lowest point of the higher sneaker (or of the one sneaker)
16. Lowest point of the lower sneaker

*Pizza

17. Highest point of the crust (if the pizza is not inverted)
18. Lowest tip of the pizza (if the pizza is not inverted)

*Solo

19. Highest point of detergent container
20. Highest point of the laundry basket
21. Lowest point of the laundry basket
22. Lowest point of detergent container

*Lawnmower

23. Midpoint of the top edge of the wheelborrow

*Horn

24. Highest point of the cone
25. Highest point of the mouthpiece

*Candle

26. Highest point of the candlestick holder
27. Lowest point of the candlestick holder

*Car

28. Highest point of the roof of the car
29. Midpoint of the bottom of the front window

30. Lowest point of the bottom of the car midway between the two tires

*Woman

31. Middle of her sunglasses
32. Bottom of her chin

*Blender

33. Midpoint of the top of the base
34. Top of the highest button

*Vase

35. Highest point of the vase
36. Midpoint of the top of the sofa
37. Lowest point of the vase

*Fruit

38. Middle of the label (Dole)

*Typewriter

39. Midpoint of the top of the page
40. Top of the front face of the typewriter
41. Lowest point of the typewriter

*Door

42. Middle of the door handle
43. Lower corner of the side of the window closest to the door
44. Average of the bottom two corners of the door

*Fan

45. Middle of the inside metal part of the fan
46. Bottom of the metal wire part of the fan
47. Midpoint of the lowest part of the base of the fan

*Television

48. Top right hand corner of the TV
49. Bottom right inside corner of the screen

*Lamp

50. Highest point of the lampshade
51. Lowest point of the front face of the lampshade

*Phone

52. Midpoint of the bottom of the receiver handle
53. Top of the middle number on the top row
54. Bottom of the middle number on the bottom row

William B. Richardson's report was not available at the time of publication.

A STUDY OF THE DEICING OF AIRCRAFT

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Final Report for:
High School Apprentice Program
Armstrong Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

and

Armstrong Laboratory

July 1996

A STUDY OF THE DEICING OF AIRCRAFT

Alejandro F. Ruiz
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Abstract

The harmful effects of ice and snow collecting on the exterior of aircraft was studied. When the weather conditions contain ice, snow, and rain, aircraft that are parked outside can contribute ice on them. By deicing, the aircraft can fly safely.

A STUDY OF THE DEICING OF AIRCRAFT

Alejandro F. Ruiz

Introduction

The purpose of aircraft deicing is to remove ice and snow from wings and fuselages. Aircraft are sprayed with a mixture of hot water and Type I aircraft deicing fluid (ADF). The ADF may contain either ethylene or propylene glycol. Ambient temperature is what determines whether Type I ADF is used or not. Hot water alone is effective at temperatures above 28 F. Deicing occurs immediately before departure, in preparation for anti-icing , and for removing used anti-icing fluids from aircraft that have been parked overnight. Under conditions of heavy snow or freezing rain, snow and ice can collect on aircraft in the period between deicing at the gate or hangar and takeoff.

Discussion of problem

Ice, snow, and frost are frozen contaminants that can form and collect on the outside of aircraft that are on the ground. They can have the thickness and surface roughness of medium or coarse sandpaper. This can reduce wing lift by as much as 30%. Drag can increase by 40%. Such changes in lift and draft can greatly increase stall speed, reduce controllability, and can even alter flight handling characteristics. As a frozen contamination gets thicker and rougher, the harmful effects also increase.

Methodology

Procedures for aircraft ground deicing depends on the type of multiplication on the surfaces, on the components of the aircraft, and the type of aircraft. There are some deicing fluids, originally developed for large commercial aircraft which can be used on small aircraft, typically those found in FAR Part 135 operations. Heating increases the deicing effectiveness, but unheated fluid is more effective for anti-icing. Deicing with fluids is a two-step procedure. It contains two separate applications. Deicing followed by anti-icing. The aircraft is deiced using hot water or a hot mixture of FPD fluid and water. This is followed by an application of SAE or ISO Type II FPD fluid for anti-icing protection.

Results

The deicing of aircraft is a necessary procedure in weather conditions containing ice and snow. The collection of ice on the aircraft can greatly increase the chances of losing control of the aircraft or an accident. By using the deicing and anti-icing fluids and following the recommendations given by manufacturers, aircraft can be cleared away of contamination.

Conclusion

An aircraft free of ice and snow will fly better and be more aerodynamic. Takeoff should not be attempted in aircraft with contaminated surfaces.

References

The Clean Aircraft Concept by Phyllis-Anne Duncan

A STUDY OF DE-ICING FLUIDS, METHODS, AND EFFECTS AS USED ON MILITARY AIRCRAFT

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Armstrong Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

and

Armstrong Laboratory

August 1996

A STUDY OF DE-ICING FLUIDS, METHODS, AND EFFECTS AS USED ON MILITARY AIRCRAFT

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Abstract

Military de-icing fluids, their types and effects on aircraft and environment, were studied. There are four types of military de-icing fluids, all of which were studied. As a preflight team deices a potentially harmful aircraft using these fluids, the runoff enters stormwater drainage systems and ground water around the airfield. Eventually these fluids will make way to nearby rivers, lakes, streams, ect. The fluids reduce the amount of oxygen in the water for microorganisms to live. De-icing and proper de-icing methods are essential for a clean aircraft thus ensuring a safe flight. By testing for the Biochemical Oxygen Demand and Chemical Oxygen Demand caused by these fluids, the perfect combination of a less polluted water system and a flight safe aircraft can be obtained.

A STUDY OF DE-ICING FLUIDS, METHODS, AND EFFECTS AS USED ON MILITARY AIRCRAFT

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Judson High School

Introduction

A pilots' job in the United States Air Force is a difficult one. To insure safety in flight a pilot must have a team of individuals to assist him or her. The preflight team has the very important job of preparing an aircraft for flight. Checking an aircraft for ice, snow, frost, or other contaminants is extremely critical in low temperatures because of the degration of performance that can occur from frozen contamination on critical surfaces. Thorough de-icing techniques can ensure a worry free flight for a pilot as well as keep the water system in a base at an acceptable level. The types of fluids and methods of using them will determine the effects on aircraft, microbial life, and a all around water system.

Fluids

There are four types of military specified de-icing fluids. These are MIL-A-4823C Type I, MIL-A-4823C Type II, MIL-A-4823D Type I, and MIL-A-4823D Type II. The type of fluid commonly used in the United States Air Force is Mil-A-8243D Type I. This type of fluid has a propylene gylcol base and provides the maximum amount of corrosion protection possible. The Environmental Protection Agency's National Pollutant Discharge Elimination System(NPDES) program is the primary source of regulation for storm water discharge permits on any USAF base. Biochemical Oxygen Demand(BOD) and Chemical Oxygen Demand(COD) tests can determine the the extent to which oxygen can be utilized by microbial life. By using these procedures, the USAF can work well within the standards set by the EPA.

Methods

Differences between civil aviation and military ground operations

To understand the military de-icing process, one must first understand there is a decided difference in the aviation ground handling philosophies of the USAF and civil aviation. Because a civilian carrier's aircraft spends a majority of its service life in flight, it usually does not accumulate large amounts of frozen precipitation. Much of the aircraft's time is spent waiting on the taxiway for clearance to the runway and the main concern is anti-icing the aircraft which is performed whenever an aircraft will encounter icing conditions during the critical take-off and climb-off portion of its flight. The USAF has a main concern of snow and ice removal, which can accumulate several hours or even days worth of frozen precipitation that needs to be removed in the parking area. The USAF usually has ample time to deice and then taxi aircraft from the parking area to the runway without delay. Also, most of the de-icing/anti-icing equipment and products are not configured or designed for use in the USAF.

Preflight Inspection Procedures

Preparing an aircraft for flight in the cold is a job that is not enjoyable. However, abbreviating a preflight could be deadly. Even though the preflight may make a person physically uncomfortable, wintertime is the time to do your most through inspection. Conducting the complete, normal preflight offers the opportunity to detect ice, snow, frost, slush, ect. which has accumulated on an aircraft. By conducting an environmentally safe and comprehensive preflight an aircraft can complete its mission to its best.

Effects of De-icing

The entire de-icing procedure has two wide-range effects. the first is to ensure a clean aircraft and the second is to keep the environment safe.

A wings lift can be reduced by as much as 30% and drag increase by 40% with ice, snow, or frost with the thickness and roughness of medium or coarse sandpaper. Changes such as these can increase stall speed, reduce controllability, and even alter flight handling characteristics. As a flight continues, contamination can thicken and increase adverse effects. This is why the preflight is so important. Understanding this can lead to an aircraft free of these worries.

It has been estimated that 28% of de-icing and anti-icing fluids that fall of an aircraft ends up in bulk snow disposal sites. Runoff from these sites could release trapped contaminants(de-icing/anti-icing fluid, hydraulic fuel, jet fuel, engine oil) into ground and surface waters during the spring. The most effective pollution prevention strategies involve de-icing in areas where fluid run off can be controlled. Testing for the BOD and COD in water that contain de-icing fluids can also help determine the best type of fluids to use. The combination of these things will help keep water systems on bases pollution free and safe for microbial life.

Conclusion

The USAF is always trying to find new and better ways to keep its aircraft in the best possible form. Although the most up to date equipment is important, safety, on all fronts, is critical. This starts in the laboratories where de-icing fluids are studied. This leads to an easier, more protective method of de-icing, a less contaminated water supply, and a proper flight.. .

ELECTROMAGNETIC FIELDS IN A SINGLE SLAB FOR OBLIQUE INCIDENCE

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Final Report for:
High School Apprentice Program
Armstrong Laboratory (AL/OES)

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Air Force Office of Scientific Research
Bolling AFB Washington DC

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Armstrong Laboratory
Brooks Air Force Base, Texas

July 1996

ELECTROMAGNETIC FIELDS IN A SINGLE SLAB FOR OBLIQUE INCIDENCE

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Abstract

A program was created and tested to calculate and plot points for electromagnetic field attributes in a single dielectric slab. The points were changed by modifying the frequency of the incoming field, the angle of incidence at which the field was coming in, and type of polarization, either transverse electric(TE) or transverse magnetic(TM) polarizations. These, in turn, were graphed so that the behavior of the electromagnetic field within an air-water-air media would be further understood. This program is just a basis program and will be preassigned properties of water and air, such as permittivity. Such a program would, in the near future, be used and modified to handle any number of slabs of any composition. Thus it would be useful for gathering information on the effects of electromagnetic propagation through the human body with its many epidermal and muscular tissue layers.

ELECTROMAGNETIC FIELDS IN A SINGLE SLAB FOR OBLIQUE INCIDENCE

Jonathan Samn
Theodore Roosevelt High School

Introduction

Accurate predictions of microwave power deposition in a single layer dielectric slab is more than an academic exercise. The single-slab predictions provide a well-understood baseline that can be compared to calculations of greater complexity, i.e. multiple layers, thereby gaining insights into the significance of various parameters and the physical processes involved. This report documents the design of a computer program for calculating the internal E & H fields in a uniform homogeneous slab illuminated by a continuous plane wave at oblique incidence. After describing the program, it is used to investigate some special cases of plane wave propagation in layered dielectrics.

Discussion

The study of oblique incidence of TEM waves on planar layered tissue dielectrics is a physically interesting example of a computational dosimetry problem that is yet amenable to analytical solution for two cases of plane polarized incident waves. Despite the simplifying assumptions of continuous waves of infinite duration and extent, planar parallel interfaces, and a medium whose permittivity varies with depth like a step function, this model is a good first approximation for microwave dosimetry computations in tissues having layered structures. For this reason, and because it can provide a standard against which to check the results of more elaborate and computationally intense computer codes, albeit for "simple" configurations of layered tissue media, a computer program was coded to predict E & H fields in a 3-medium, 2-interface configuration consisting of a single dielectric slab sandwiched between two half-spaces of arbitrary permittivity and conductivity. This code is a necessary first step towards the goal of a generalized code that will handle n-layered, bio-tissue, dosimetric calculations to be completed in the near future.

Methodology

The computer program, obl2.f, is a straight forward implementation in FORTRAN of the analytical solution of Maxwell's equations for a steady-state, monochromatic plane wave obliquely incident on linear, homogeneous, isotropic, multi-layered media. The required user inputs are the incident E-field magnitude, angle of incidence, and polarization(TE and TM). When the magnetic field vector is in the x-z plane(Fig 1a) it is called transverse electric (TE) polarization. When the electric field vector is in the x-z plane(Fig 1b) it is called transverse magnetic (TM) polarization. In addition, the user must specify the thickness and electrical properties (permittivity, permeability, and conductivity) of each layer. The program computes the TE or TM Fresnel reflection coefficients associated with each interface. Next, it recursively computes the generalized or combined reflection coefficients as given by Chew [1]. Finally, the user can request computation of the amplitudes and phases of the forward and backward traveling waves for arbitrary (x,z,t) in each layer, or the user can request computation of local power density in the lossy layers for arbitrary (x,z). This methodology guarantees continuity of the E & H tangential field components across all boundaries as required by Maxwell's equations. The obl2.f program was validated by comparing its outputs against another program which implemented a direct solution of Maxwell's equations satisfying the boundary conditions but which was formulated without use of reflection coefficients.

The general solution obtained for plane polarized waves at oblique incidence is given in Appendix-A for the two polarizations. This solution is for the forward and backward propagating waves that exist within the slab due to reflections at the slab boundaries. The advantage of using the generalized reflection coefficients given by Chew[1] is that for three layers, reflection takes place at not only the first interface but at the second interface as well. The reflected wave in medium 1 is thus made up of the reflections from both surfaces. To fully account for these successive reflections, the generalized reflection coefficient, $\Re_{i,i+1}$, is used. Appendix-A shows how $\Re_{i,i+1}$ is recursively computed thereby incorporating the reflections from both surfaces. For the 3rd(last) layer, $\Re_{3,4} = 0$. For the 2nd(middle) layer, $\Re_{2,3} = R_{2,3}$, i.e. the generalized reflection coefficient of layer 2 is equal to the Fresnel reflection coefficient associated with the interface separating media 2 and 3. The generalized reflection coefficient of the 1st layer, $\Re_{1,2}$, will be useful for calculating the energy absorbed by the lossy water slab to be discussed later in this paper.

Results:

In all of the results, an incident electric field of 1 Volt per meter or incident power density of $|E_{inc}|^2 / Z_{air} = 1/120\pi$ Watts per square meter was used. Also, all field and power densities were computed and observed with the time and transverse coordinate(x) both set to zero.

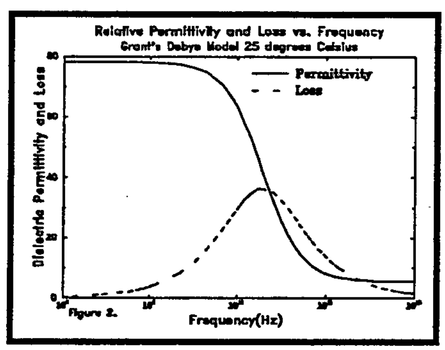


Figure 2.

The first use of the program obl2.f was the study of electromagnetic propagation in an air-water-air media where the water is a dielectric slab with finite thickness. The properties of this dielectric slab are accurately modeled using Grant's curve fit formula:

$$\tilde{\varepsilon}(\omega) = \varepsilon_\infty + \left\{\frac{\varepsilon_s - \varepsilon_\infty}{1 + i\omega\tau}\right\} - \frac{i\sigma_c}{\omega\varepsilon_0},s$$

at 25°C and with the following parameters:

$\varepsilon_\infty = 5.5$ $\quad\tau = 8.1 \times 10^{-12}(\text{sec})$ $\quad\varepsilon_s = 78.2$ $\quad\sigma_c = 10^{-5}(Sm^{-1})$.

With these parameters, the measured data agreed with the frequency dependence of Grant's model.(Fig 2)

Using the program obl2.f, with the selected frequencies, 500 MHz, 1 GHz, 2.45 GHz, and 6 GHz, the magnitudes of the Fresnel reflection coefficients were plotted for all angles between and including 0 and 90 degrees. These are plotted for both TE and TM polarizations in Figure 3. From this we observed that for TM polarization, the reflection coefficient becomes smaller as the angle of incidence becomes larger. We also note that there is almost no reflected wave when the angle of incidence for the TM wave approaches the polarizing or Brewster angle. This angle for water is approximately 83.5 degrees.

To verify our computations, the incident, reflected and transmitted E and H fields as well as the internal fields in a 20mm slab of water were plotted.(Fig 4) For this plot, normal, 30 degree, 60 degree, and Brewster angle incidences were used for the 2.45 GHz frequency propagation. It was observed that for all angles, E & H field tangential components do not change when crossing a boundary.

For the next use of the program, the selected frequencies and also 3 GHz, and the selected angles of incidence, 0, 30, 60 and 83.5 degrees produced various examples of TM and TE polarization in a dielectric slab. (Fig 5-9) In the 20mm water slab, oscillating behavior of computed power density has occurred. This behavior was due to reflections at the boundaries of the slab which caused standing waves.(Fig 6,7,8) It was also noted in Figure 10 for normal incidence that at a frequency of 2.45 GHz, the distance between peaks of the power density is approximately 7mm which can be proved with the equation: $d_{peak} = m \cdot (1/2)\lambda / \sqrt{\varepsilon_{water}}$,where the distance is equal to half multiples of the water wavelength.

Also with the use of the program, the generalized reflection coefficient and percent of power absorbed throughout the depth of a dielectric slab could be plotted.(Fig 10) From this plot, we see that the generalized reflection coefficient approached asymptotically to 0.79 when depth increased. This value is the same as the value of the Fresnel coefficient for the air-water interface at 0 degree incidence. Similarly, the percent power absorption approaches 36%, which is the value for an air-water half-space at normal incidence.

It was also found that not all TM polarizations have oscillating behaviors. In a particular case, at the Brewster angle, it is observed that there are no localized energy concentrations caused by standing waves. This would indicate that the absorbed power density is almost 100%.(Fig 11b) It can be calculated with the equation:

$$P(\%) = (1 - |\Re_{1,2}|^2).$$

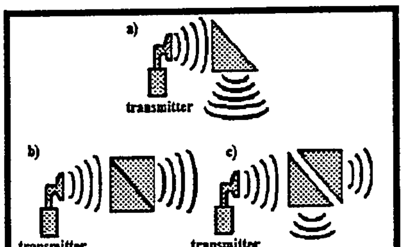


Figure 13.

The next results from the program were from its use to demonstrate microwave tunneling effects. (Fig 12) The results showed were a numerical reproduction of the experimental results described in Feynman Vol. II, chapter 33 [2] for paraffin prisms. (Fig 13) When the distance between prisms is large and the angle of incidence is greater than the critical angle, all microwaves reflect off the surface. But, when the distance between the prisms is less than a wavelength, the microwaves go straight through. The critical angle can be calculated by: $\theta_c = \arcsin(1 / n_{paraffin})$.

The program finally was used to simulate the behavior of a quarter-wave plate. This demonstrated that the plate eliminated all reflected waves which had 0 degree incidence on a paraffin half-space.(Fig 14)

Conclusion:

From a set of equations a program was created, tested, described, and implemented. It computed the E and H fields within a dielectric slab for either TE or TM polarizations in cases of different frequencies and angles of incidence. Also it simulated microwave "tunneling" between paraffin half-spaces separated by a thin gap of air for incidence angles greater than the critical angle. Finally it demonstrated the behavior of a quarter-wave plate at normal incidence. Though it is just a small program limited to a single water slab and three media, it is the first step for future programs which will be used to understand the behaviors of microwaves in layered bio-tissues and other examples of electromagnetic propagation for oblique incidence. Thus, this program opens up different paths for future study of electromagnetic waves.

References:

[1] Chew, *Waves and Fields in Inhomogeneous Media*, (Van Nostrand Rheinhold, 1990), Chapter 2, pp. 48-53.

[2] Feynman, Leighton and Sands, *The Feynman Lectures on Physics: Vol. II*, (Addison-Wesley Publishing Co., 1964), Chapter 33.

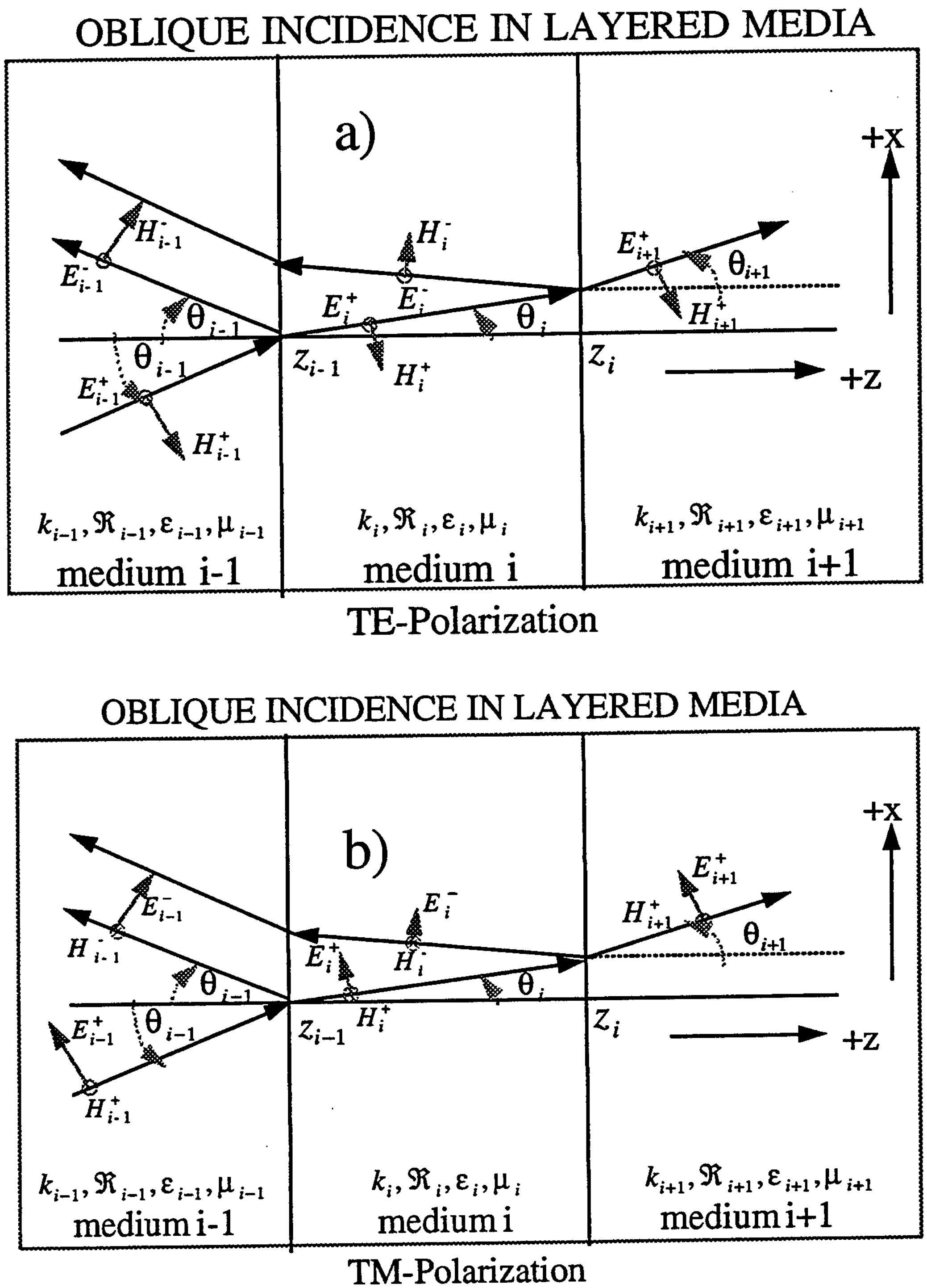

OBLIQUE INCIDENCE IN LAYERED MEDIA
a)
+x
+z
H^-_{i-1}
E^-_{i-1}
θ_{i-1}
θ_{i-1}
E^+_{i-1}
H^+_{i-1}
H^-_i
E^+_i
E^-_i
θ_i
z_{i-1}
H^+_i
E^+_{i+1}
θ_{i+1}
H^+_{i+1}
z_i
$k_{i-1}, \Re_{i-1}, \varepsilon_{i-1}, \mu_{i-1}$
medium i-1
$k_i, \Re_i, \varepsilon_i, \mu_i$
medium i
$k_{i+1}, \Re_{i+1}, \varepsilon_{i+1}, \mu_{i+1}$
medium i+1
TE-Polarization
OBLIQUE INCIDENCE IN LAYERED MEDIA
b)
+x
+z
E^-_{i-1}
H^-_{i-1}
θ_{i-1}
θ_{i-1}
E^+_{i-1}
H^+_{i-1}
E^-_i
E^+_i
H^-_i
θ_i
z_{i-1}
H^+_i
E^+_{i+1}
H^+_{i+1}
θ_{i+1}
z_i
$k_{i-1}, \Re_{i-1}, \varepsilon_{i-1}, \mu_{i-1}$
medium i-1
$k_i, \Re_i, \varepsilon_i, \mu_i$
medium i
$k_{i+1}, \Re_{i+1}, \varepsilon_{i+1}, \mu_{i+1}$
medium i+1
TM-Polarization

Figure 1.

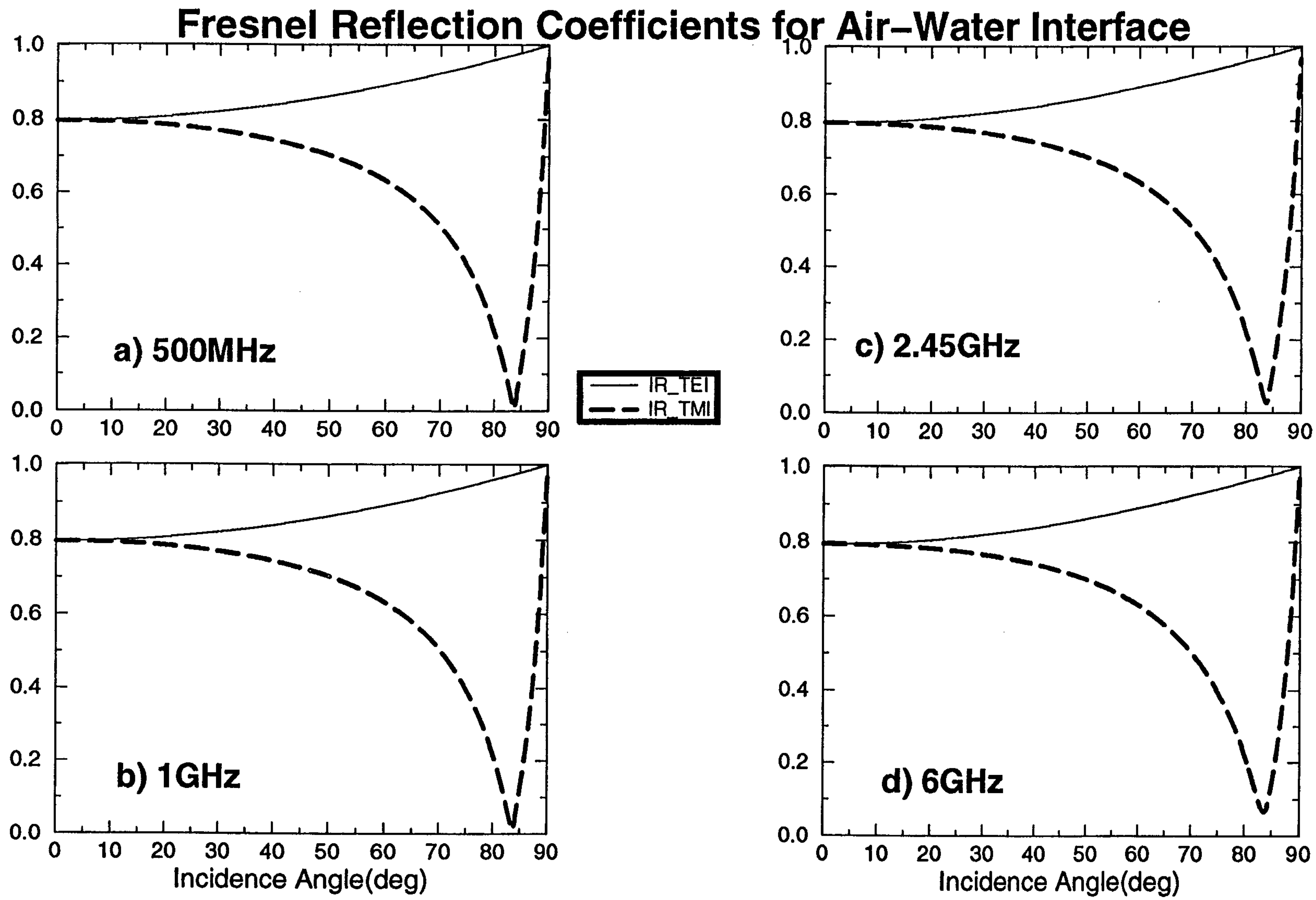


Figure 3. Grant's Debye Model at 25 degrees Celsius.

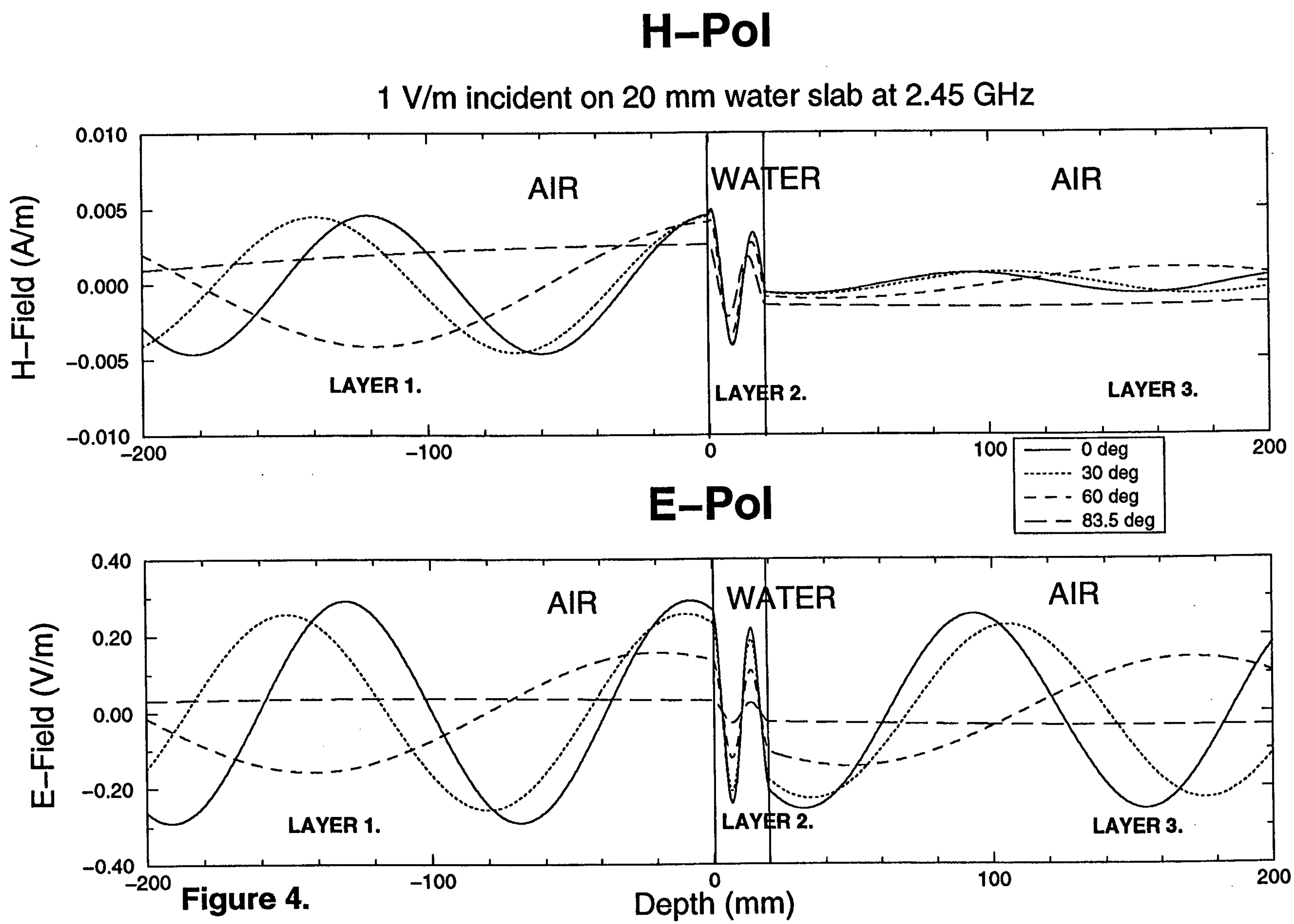

H–Pol
1 V/m incident on 20 mm water slab at 2.45 GHz
H–Field (A/m)
0.010
0.005
0.000
−0.005
−0.010
AIR
WATER
AIR
LAYER 1.
LAYER 2.
LAYER 3.
−200
−100
0
100
200
0 deg
30 deg
60 deg
83.5 deg
E–Pol
E–Field (V/m)
0.40
0.20
0.00
−0.20
−0.40
AIR
WATER
AIR
LAYER 1.
LAYER 2.
LAYER 3.
−200
−100
0
100
200
Depth (mm)

Figure 4.

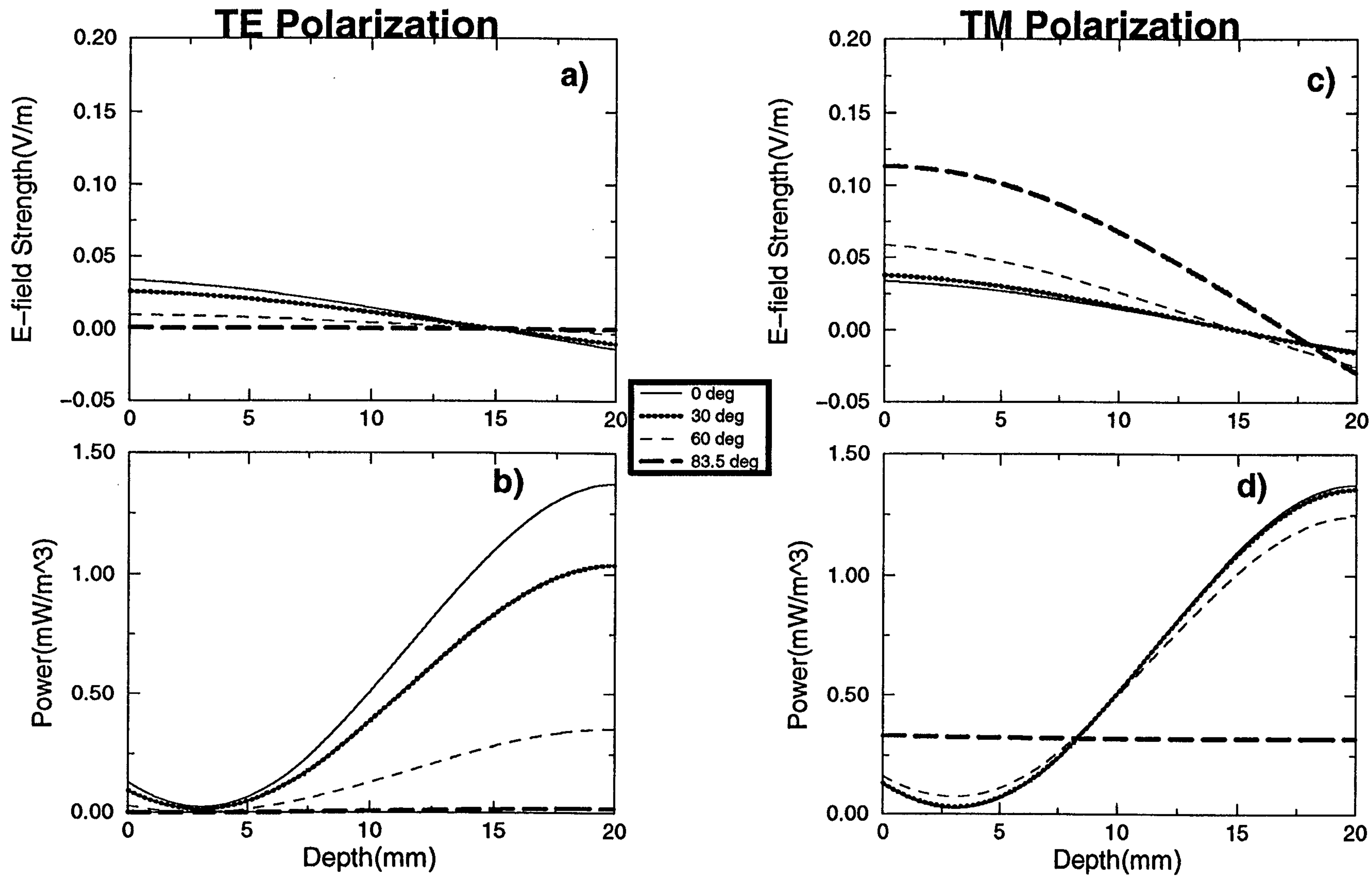


Figure 5. **500MHz in a dielectric slab of water with thickness of 20mm.**
a) E–field strength for Transverse Electric(TE) Polarization. b) Power for TE.
c) E–field strength for Transverse Magnetic(TM) Polarization. d) Power for TM.

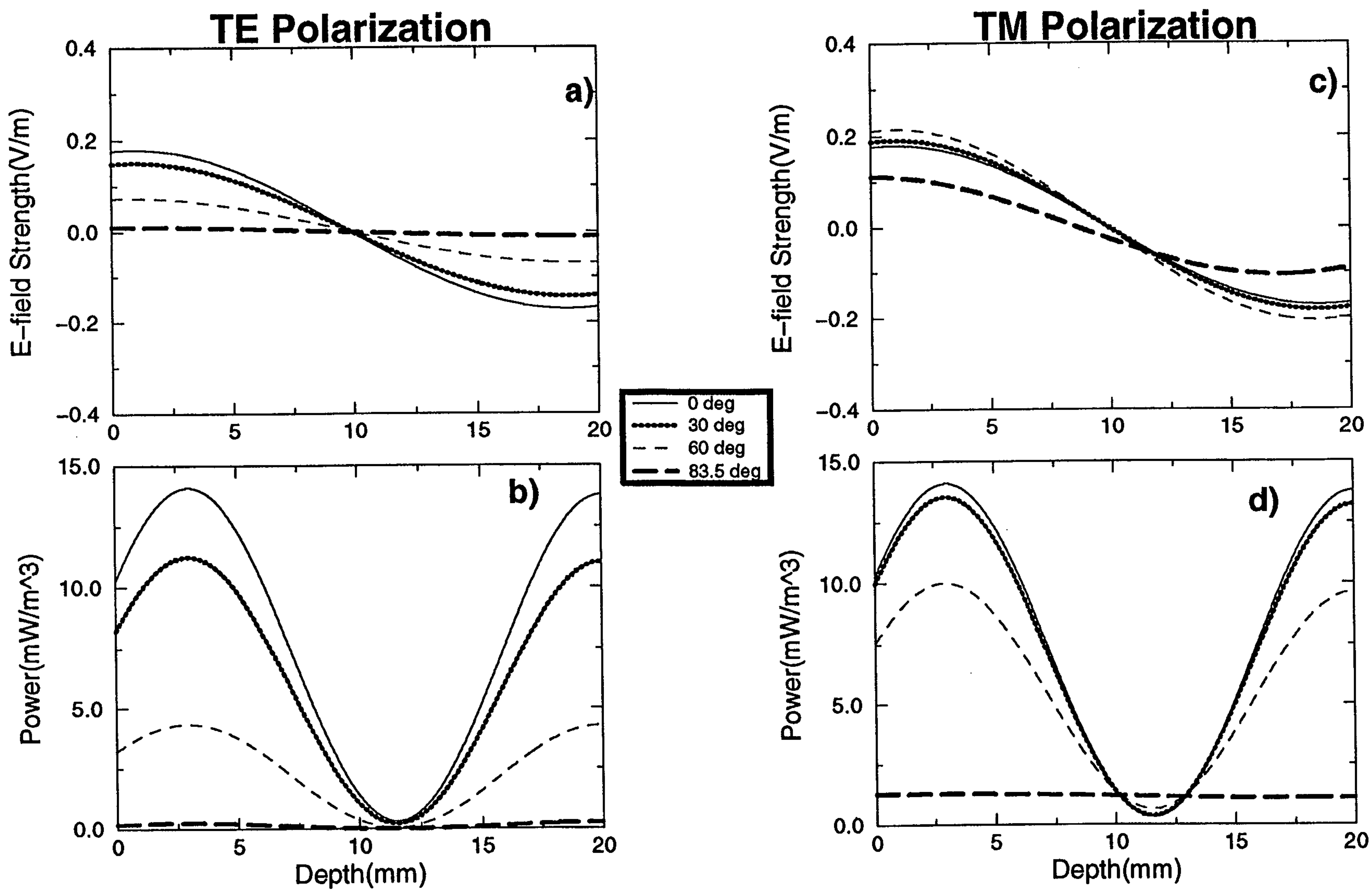


Figure 6. 1GHz in a dielectric slab of water with thickness of 20mm.
a) E–field strength for Transverse Electric(TE) Polarization. b) Power for TE.
c) E–field strength for Transverse Magnetic(TM) Polarization. d) Power for TM.

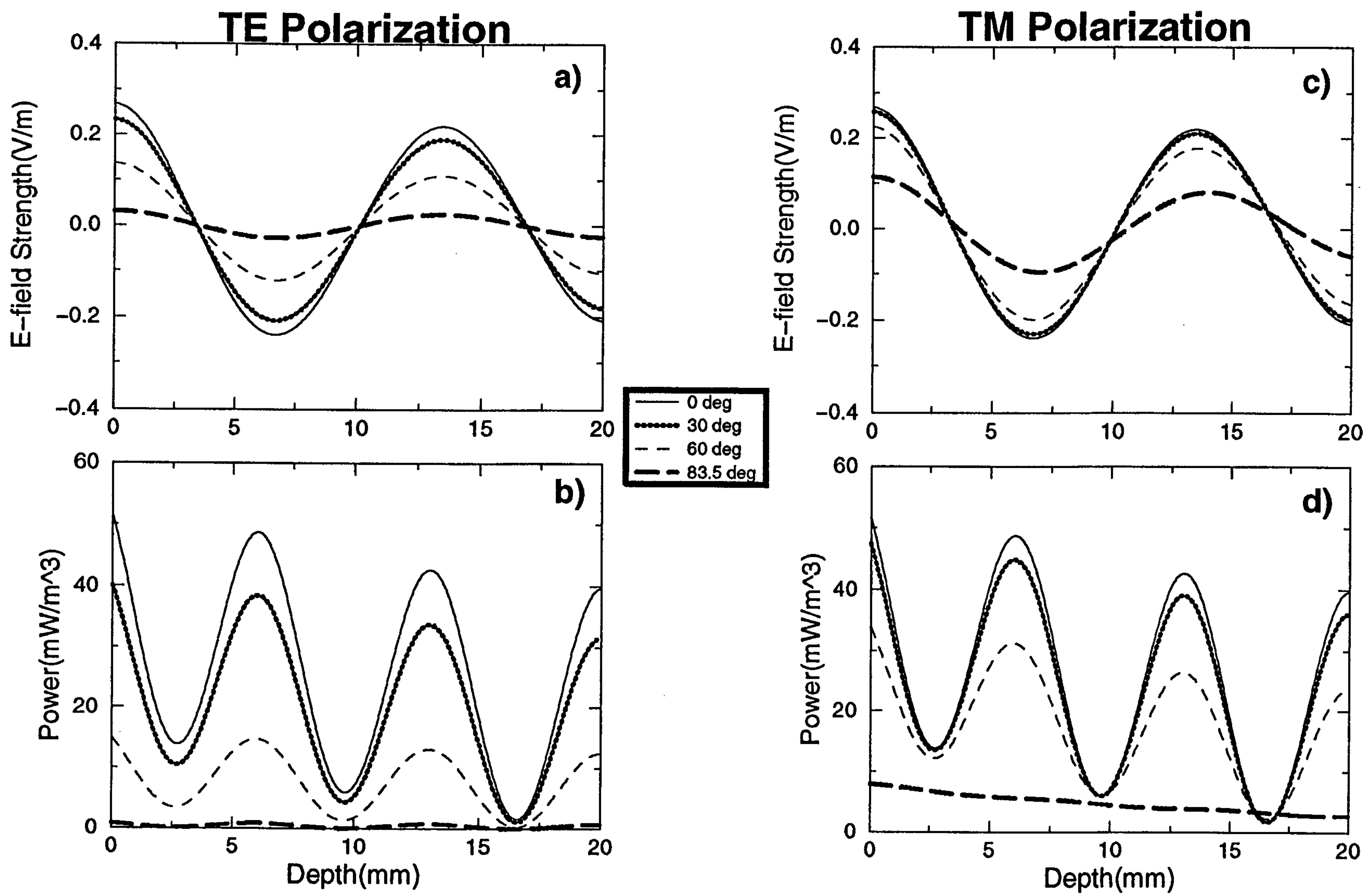


Figure 7. 2.45GHz in a dielectric slab of water with thickness of 20mm.
a) E–field strength for Transverse Electric(TE) Polarization. b) Power for TE.
c) E–field strength for Transverse Magnetic(TM) Polarization. d) Power for TM.

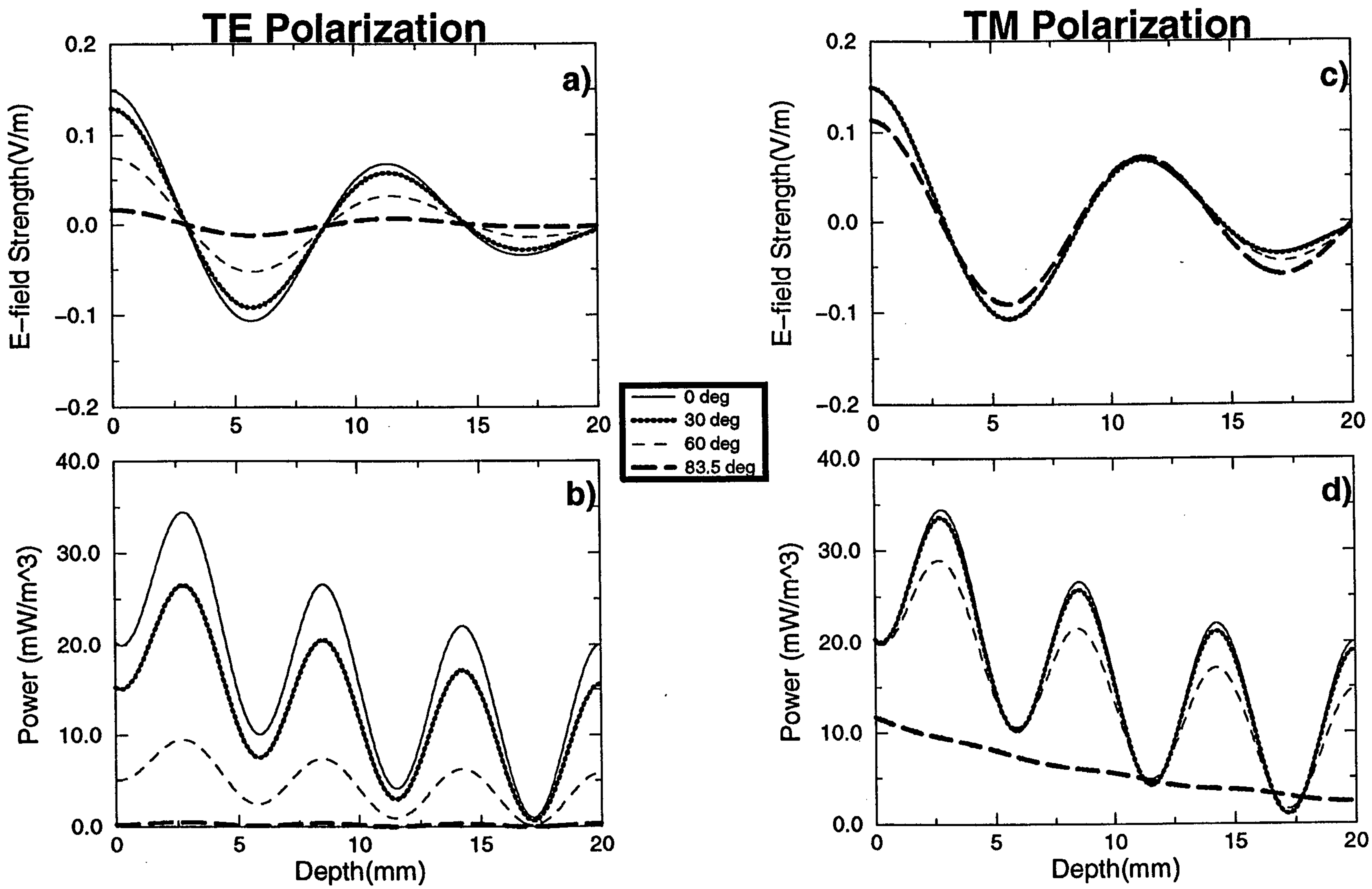


Figure 8. 3GHz in a dielectric slab of water with thickness of 20mm.
a) E-field strength for Transverse Electric(TE) Polarization. b) Power for TE.
c) E-field strength for Transverse Magnetic(TM) Polarization. d) Power for TM.

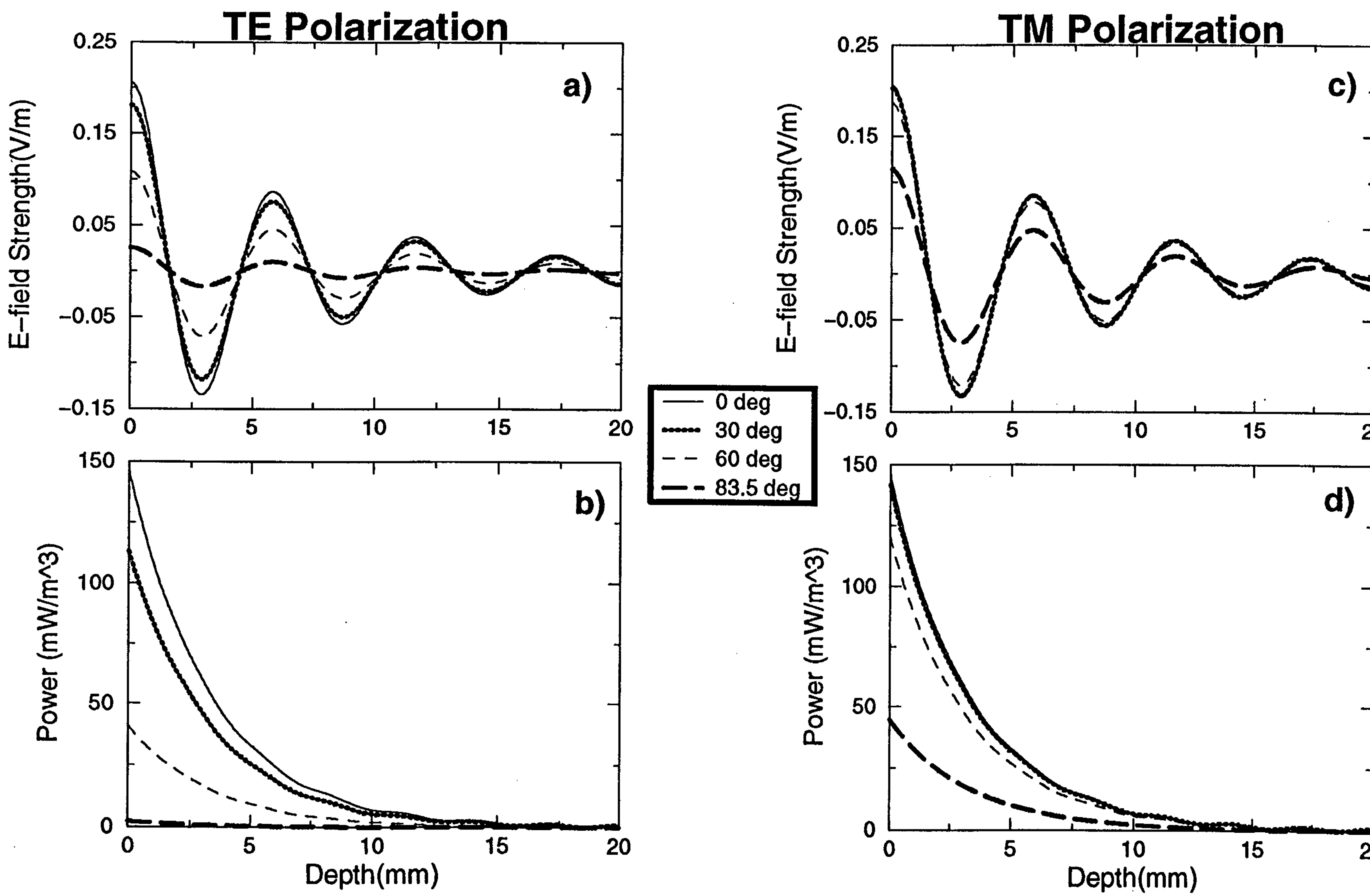
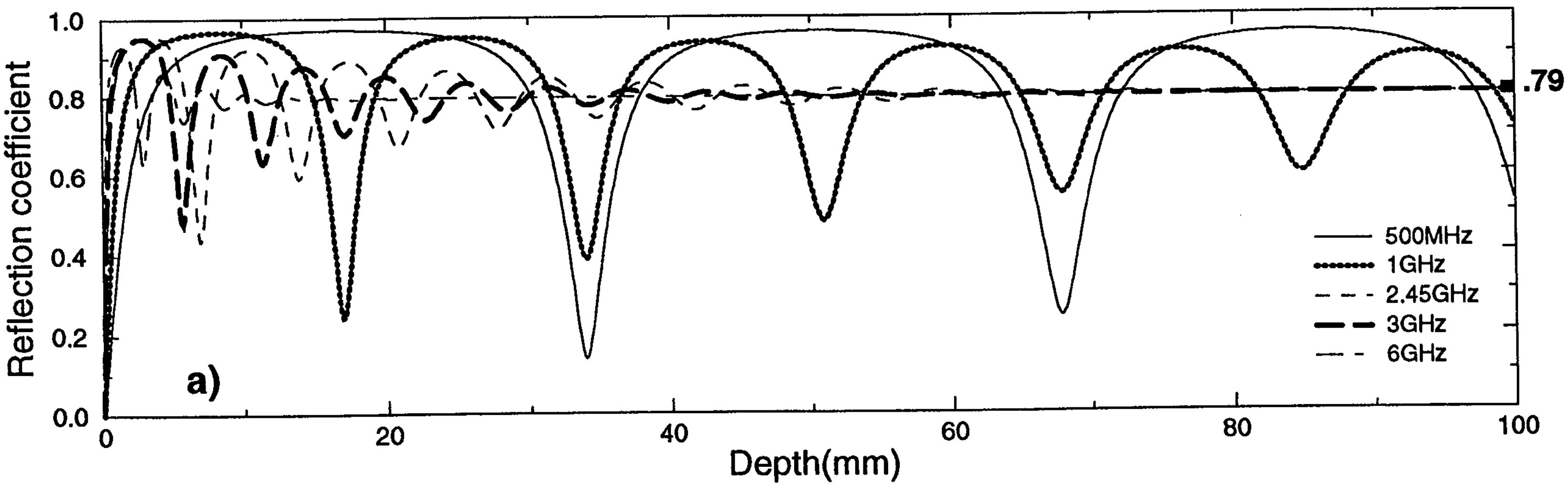


Figure 9. 6GHz in a dielectric slab of water with thickness of 20mm.
a) E–field strength for Transverse Electric(TE) Polarization. b) Power for TE.
c) E–field strength for Transverse Magnetic(TM) Polarization. d) Power for TM.

Generalized Reflection Coefficient($\Re_{1,2}$) vs Depth

(Normal incidence, 100mm of water, selected frequencies)



Percent Power Absorption vs Depth

(Normal incidence, 100mm of water, selected frequencies)

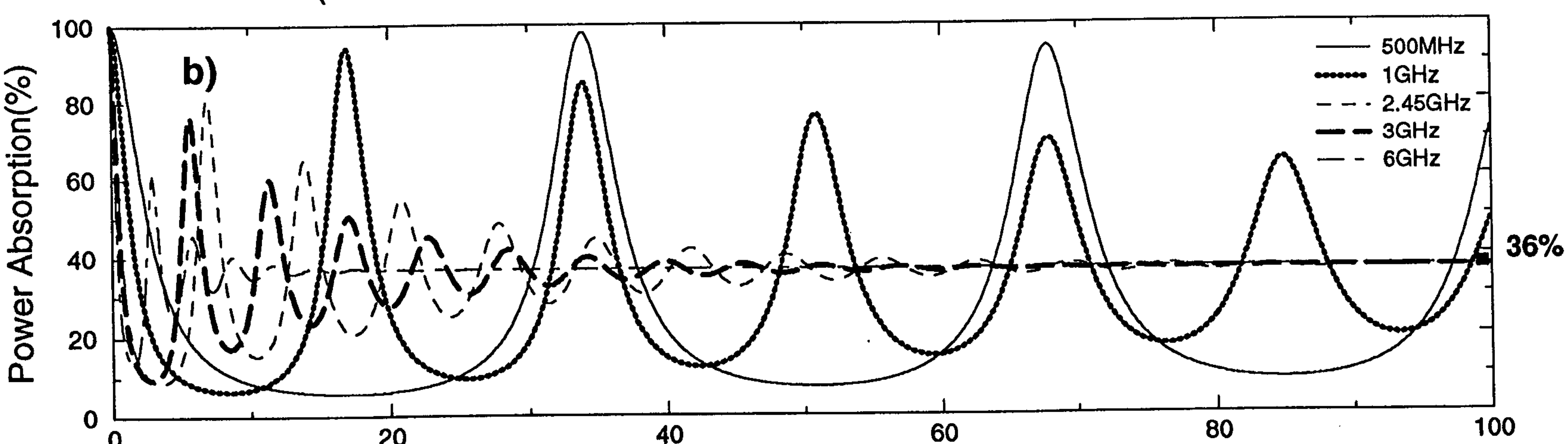


Figure 10.

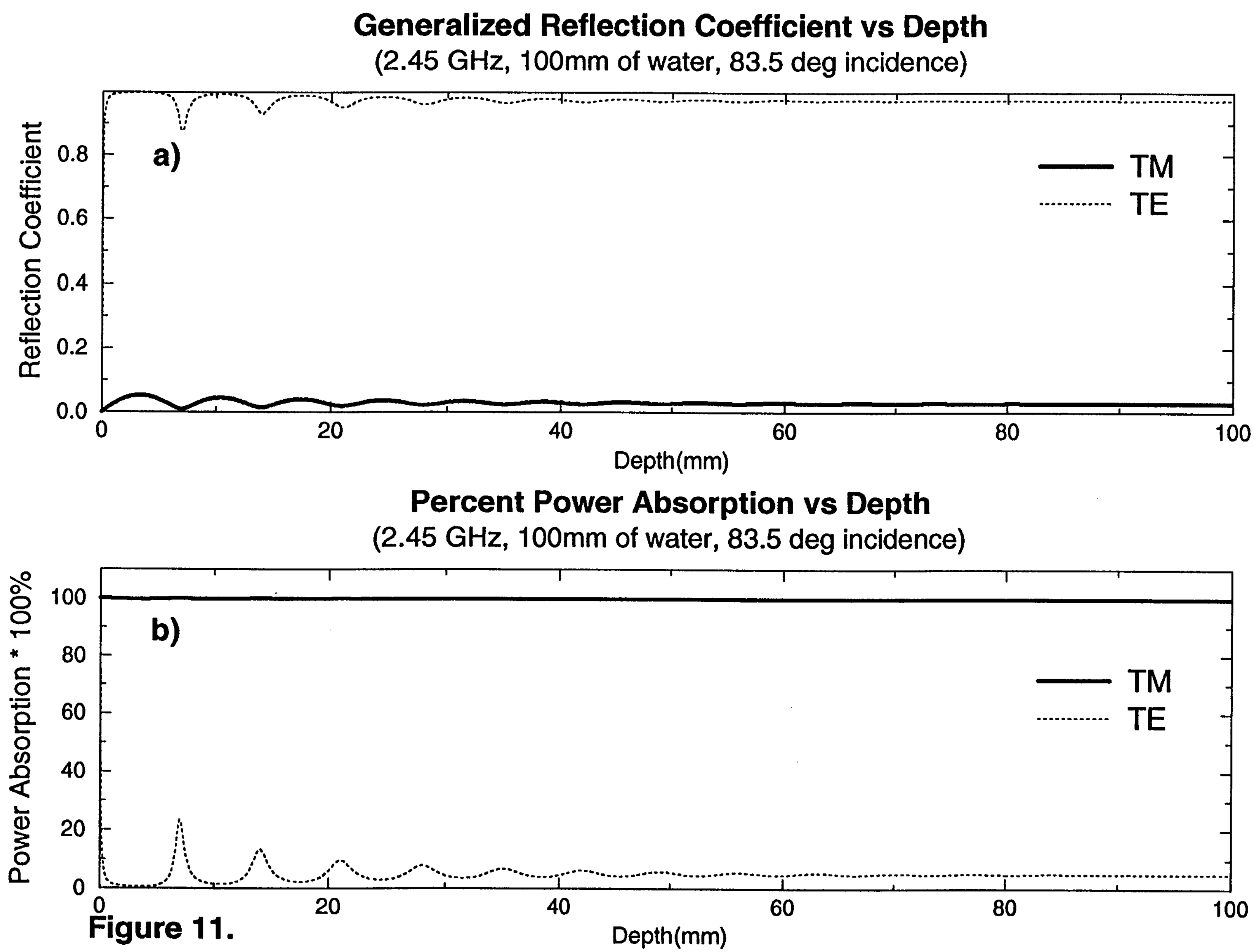

Generalized Reflection Coefficient vs Depth
(2.45 GHz, 100mm of water, 83.5 deg incidence)
a)
Reflection Coefficient
0.0
0.2
0.4
0.6
0.8
0
20
40
60
80
100
Depth(mm)
TM
TE
Percent Power Absorption vs Depth
(2.45 GHz, 100mm of water, 83.5 deg incidence)
b)
Power Absorption * 100%
0
20
40
60
80
100
0
20
40
60
80
100
Depth(mm)
TM
TE

Figure 11.

Microwave 'Tunneling', Critical Angle= 41.5 deg.

E–Pol, IOR=1.5, fc=2.45 GHz, incident angle=50 deg., lambda=122.36 mm

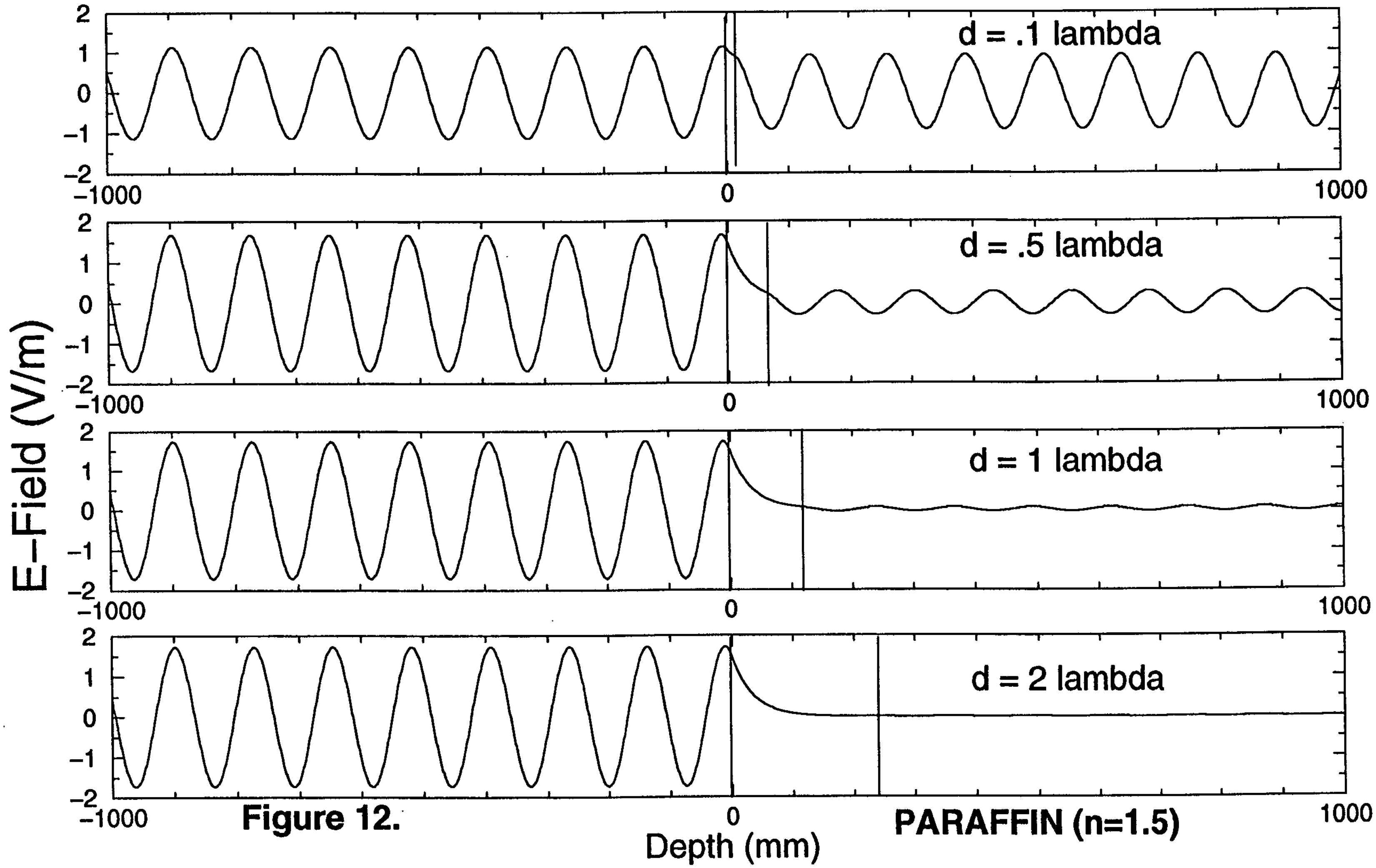


Figure 12. **PARAFFIN (n=1.5)**

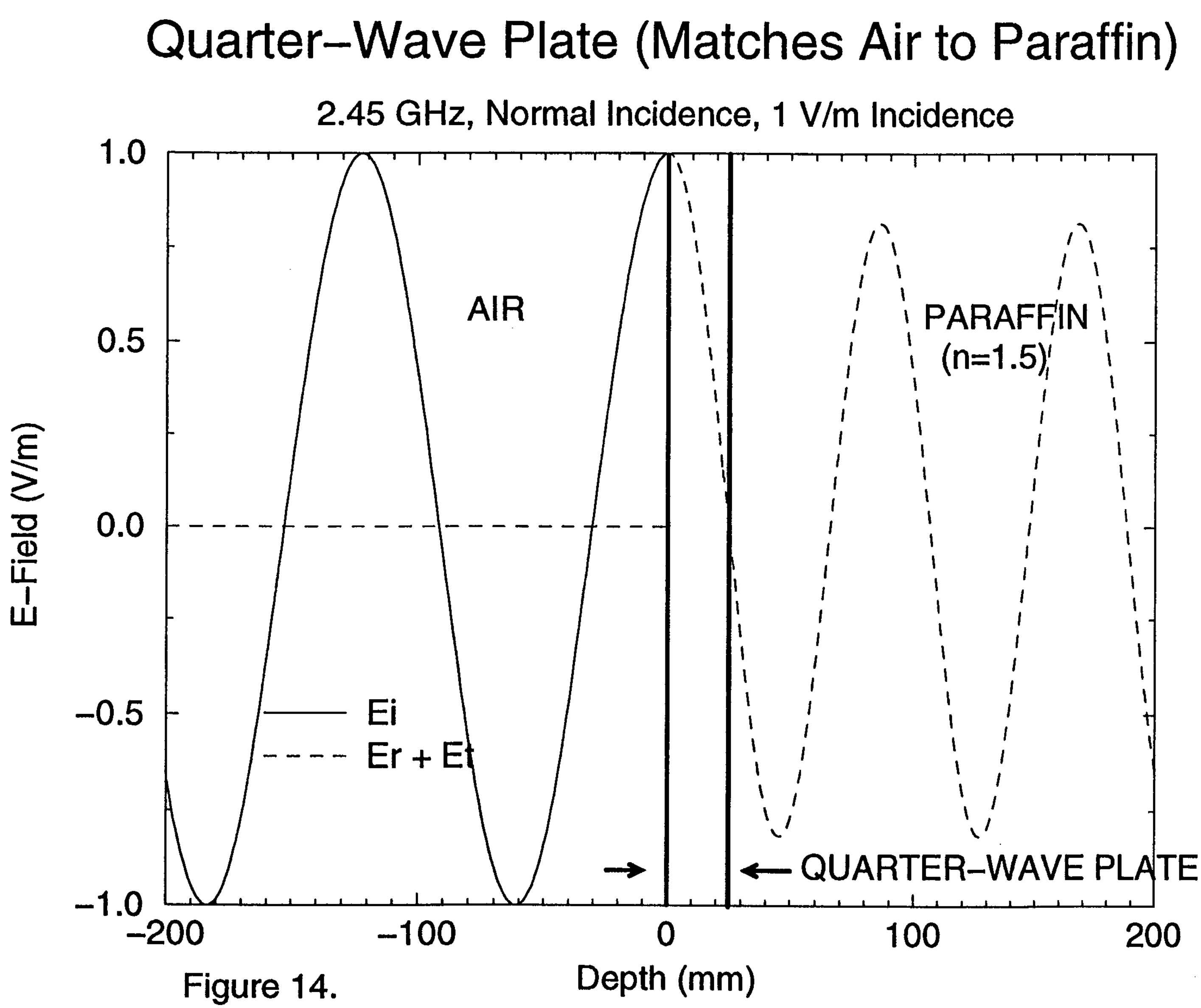

Quarter–Wave Plate (Matches Air to Paraffin)
2.45 GHz, Normal Incidence, 1 V/m Incidence
E–Field (V/m)
1.0
0.5
0.0
−0.5
−1.0
−200
−100
0
100
200
Depth (mm)
AIR
PARAFFIN
(n=1.5)
Ei
Er + Et
QUARTER–WAVE PLATE

Figure 14.

Appendix - A

Solution of plane polarized waves with oblique incidence

TE - Polarization:

$$E_{y,i}(x,z,t) = E^+_{y,i} + E^-_{y,i}$$

$$E^+_{y,i} = E^+_i \exp\{j(k_{x,i}x - k_{z,i}z - \omega t)\}$$

$$E^-_{y,i} = E^-_i \exp\{j(k_{x,i}x + k_{z,i}z - \omega t)\}$$

$$E^-_i = E^+_i \Re_{i,i+1} \exp\{2jk_{z,i}z_i\}$$

$$E^+_{i+1} = E^+_i \frac{(1 + R_{i,i+1}) \exp\{jz_i(k_{z,i} - k_{z,i+1})\}}{1 + R_{i,i+1}\Re_{i+1,i+2} \exp\{2jk_{z,i+1}(z_{i+1} - z_i)\}}$$

$$\Re_{i,i+1} = \frac{R_{i,i+1} + \Re_{i+1,i+2} \exp\{2jk_{z,i+1}(z_{i+1} - z_i)\}}{1 + R_{i,i+1}\Re_{i+1,i+2} \exp\{2jk_{z,i+1}(z_{i+1} - z_i)\}}$$

$$R_{i,i+1} = \frac{\mu_{i+1}k_{z,i} - \mu_i k_{z,i+1}}{\mu_{i+1}k_{z,i} + \mu_i k_{z,i+1}} \quad , \quad \mu_{i+1} = \mu_i = \mu_0 \quad , \quad \Rightarrow \quad R_{i,i+1} = \frac{k_{z,i} - k_{z,i+1}}{k_{z,i} + k_{z,i+1}}$$

$$k_i = \frac{\omega}{c} n_i \quad , \quad k_{x,i+1} = k_{x,i} \quad , \quad k_{z,i+1} = \sqrt{\frac{n^2_{i+1}}{n^2_i} k^2_i - k^2_{x,i}}$$

$$n_i = \sqrt{\varepsilon^*_i}$$

$$\varepsilon^*_i = \varepsilon'_i + j\varepsilon''_i \quad \Rightarrow \quad \{e^{-j\omega t} \quad \text{time convention}\}$$

TM - Polarization:

$$H_{y,i}(x,z,t) = H^+_{y,i} + H^-_{y,i}$$

$$H^+_{y,i} = H^+_i \exp\{j(k_{x,i}x - k_{z,i}z - \omega t)\} = +E^+_i \;/\; Z_{0,i} \exp\{j(k_{x,i}x - k_{z,i}z - \omega t)\}$$

$$H^-_{y,i} = H^-_i \exp\{j(k_{x,i}x + k_{z,i}z - \omega t)\} = -E^-_i \;/\; Z_{0,i} \exp\{j(k_{x,i}x - k_{z,i}z - \omega t)\}$$

$$H^-_i = H^+_i \Re_{i,i+1} \exp\{2jk_{z,i}z_i\}$$

$$H^+_{i+1} = H^+_i \frac{(1 + R_{i,i+1}) \exp\{jz_i(k_{z,i} - k_{z,i+1})\}}{1 + R_{i,i+1}\Re_{i+1,i+2} \exp\{2jk_{z,i+1}(z_{i+1} - z_i)\}}$$

$$\Re_{i,i+1} = \frac{R_{i,i+1} + \Re_{i+1,i+2} \exp\{2jk_{z,i+1}(z_{i+1} - z_i)\}}{1 + R_{i,i+1}\Re_{i+1,i+2} \exp\{2jk_{z,i+1}(z_{i+1} - z_i)\}}$$

$$R_{i,i+1} = \frac{\varepsilon_{i+1} k_{z,i} - \varepsilon_i k_{z,i+1}}{\varepsilon_{i+1} k_{z,i} + \varepsilon_i k_{z,i+1}}$$

Dielectric constants:

$$Z_{0,i} = \sqrt{\frac{\mu_0}{\varepsilon_0 \varepsilon^*}}$$

$$\varepsilon_1' = \varepsilon_2' = 1 \quad , \quad \varepsilon_1'' = \varepsilon_2'' = 0 \quad , \quad air$$

$$\left.\begin{aligned} \varepsilon_2' &= \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + \omega^2 \tau^2} \\ \varepsilon_2'' &= \frac{(\varepsilon_s - \varepsilon_\infty)\omega\tau}{1 + \omega^2\tau^2} + \frac{\sigma_c}{\omega \varepsilon_0} \end{aligned}\right\} \quad , \quad water$$

$$\varepsilon_\infty = 5.5, \quad \varepsilon_s = 78.2, \quad \tau = 8.1 \times 10^{-12} \text{ (sec)}, \quad \sigma_c = 10^{-5} \text{ (S/m)}$$

$$\omega = 2\pi f, \quad j = \sqrt{-1}, \quad c = 299792458 \ (m/s), \quad \mu_0 = 4\pi \times 10^{-7} (H/m), \quad \varepsilon_0 = \frac{1}{c^2 \mu_0} \ (F/m)$$

power density:

$$P_i(z) = \pi f \varepsilon_0 \varepsilon_i'' \left| E_{y,i}(z) \right|^2, \quad (W/m^3)$$

ANALYSIS OF POLY-ALPHA OLEPHIN BY GAS CHROMATOGRAPHY

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Final Report for:
High School Apprenticeship Program
Armstrong Laboratory

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

and

Armstrong Laboratory

July 1996

ANALYSIS OF POLY-ALPHA OLEPHIN BY GAS CHROMATOGRAPHY

Keith A. Shaw
MacArthur High School

Abstract

A gas chromatographic method was attempted to analyze and successfully quantitate the heat exchanger Poly-alpha olephin (PAO). Methods of sample injection included a Dynatherm ACEM 900 sample tube collection, a porous glass diffusion chamber, and air sample output from an On-Board Oxygen Generating System (OBOGS). The results were sometimes erratic and generally inconsistent due to difficulty in desorbing the PAO from an adsorption tube. Experimental results indicate that gas chromatography would not be a satisfactory method for analyzing PAO in the gas phase in low (ppm) concentrations.

ANALYSIS OF POLY-ALPHA OLEPHIN BY GAS CHROMATOGRAPHY

Keith A. Shaw

Introduction

Poly-alpha olephin (PAO) is used in numerous aircraft as a heat exchanger fluid for cooling various systems, and the possibility exists that some Air Force aircraft using PAO to cool inlet air for aircraft oxygen systems could develop leaks. This could result in PAO contamination of those systems. One of the systems that faces possible contamination is the On-Board Oxygen Generating System (OBOGS), which supplies oxygen for the aircraft crew to breath. In order to understand the effect that PAO contamination would have on the OBOGS oxygen output, the OBOGS system must be run in a laboratory environment while being challenged with a PAO-contaminated airstream. The product flow (oxygen enriched output) must then be analyzed to determine the extent to which the PAO passed through the system into the oxygen product gas.

Properties of Poly-alpha olephin

Poly-alpha olephin is a synthetic base fluid (Royco 602 CAS 68649-12-7) composed of highly branched, compact and very stable molecules blended with additives to provide long term storage stability.

Physical Properites

- Flash point- 216 C
- Autoignition temp.- 343 C
- Density
  - 0 Deg C- 0.8058 g/cc
  - 100 deg C- 0.7392 g/cc
  - 190 deg C- 0.6768 g/cc

Material Safety Data Sheet Information

Acute Oral LD50- NA

Acute Dermal LD50- NA

Acute Inhalation LD50- NA

Prolonged exposure may cause eye or skin irritation

Occupational exposure limits

PEL/TWA- 5 mg/m^3

PEL/CEILING- NA

TLV/TWA- 5 mg/m^3

TLV/STEL- 10 mg/m^3

Not listed as a carcinogen

Methodology

The instrumentation that was available and seemed most fit to carry out the task was a Hewlett Packard 5890 gas chromatograph and a Dynatherm ACEM 900 adsorption/desorption unit. The chromatograph utilized a 0.53 mm diameter, 30 meter HP-1, a crosslinked methyl silicone gum column (HP Part # 190952-123). The Poly-alpha olephin (PAO) was first dissolved in hexane at a concentration of one microgram per milliliter. This solution could then be injected at quantities varying between one and five microliters onto a sample adsorption tube in a Dynatherm ACEM 900. The tube is then heated and a stream of inert gas funnels the contents of the tube to the chromatograph.

Another approach attempted was to take an external airstream sampling onto the adsorption tube. An air stream was passed through a chamber which contained a Corning 7930 porous glass tube filled with PAO. The PAO was picked up by the airstream and collected as it passed through the sample adsorption tube. The same procedure was then followed for transfer to the chromatograph. Unfortunately, the chromatogram of the PAO indicates the existence of three barely distinguishable peaks whose retention times are quite similar. In order to distinguish the various peaks more clearly, a different column was installed in the chromatograph. The new column, a 0.20 mm diameter, 50 meter long PONA (HP Part # 19091S-001), was recommended as being more suitable for analyzing larger hydrocarbons. The actual differences between the two columns are subtle.

The problems encountered with these approaches stem from the compound's characteristics as a heat exchanger: ie, low vapor pressure and possibly high boiling point. Because of these characteristics, the sample adsorption tube cannot be heated to a high enough temperature to purge off greater than ninety percent of the PAO. Even when heated for over 15 minutes at 350 degrees (the temperature limit) much of the PAO remains and appears in subsequent runs containing no additional sample. It would be desirable to purge the adsorption tube of at least ninety-five to ninety-nine percent of the PAO for consideration as a quantitative method.

Results

Direct microliter injection into the adsorption tube resulted in PAO contamination of the packing material inside the collection tube. Recent tests have been made with alternate column packing materials, including crushed porous glass and teflon, but with little success. Use of the porous glass chamber not only contaminated the sample tube, but also the workings of the Dynatherm fast flow vacuum interface, which directs the flow of the incoming airstream. With the excessive contamination, it becomes impossible to establish an accurate baseline to compare the amounts and concentrations of different PAO samples. Without the ability to create a calibration curve or accurately test successive samples for reproducibility no definitive conclusions can be drawn regarding the test of an outside source, and the method becomes useless. Figure 1 shows a chromatogram made after a three microliter injection of the aforementioned hexane/PAO solution followed by two subsequent runs without further injections. The two runs which follow the original retain much of the peak height of the original chromatogram, demonstrating the degree to which the PAO cannot be desorbed from the adsorption tube. One solution to this problem would be direct injection of liquid PAO into the chromatograph column. While this would avoid the contamination plaquing the other methods, it was not attempted because the eventual method would need the capability to analyze PAO in the gaseous state where large volumes (1-50L) of gas would be required in order to obtain sufficient PAO for analysis.

Conclusion

The purpose of studying PAO was to develop methodology to accurately assess it presence and concentration in the gaseous state. Without the ability to do a direct column injection into the chromatograph, testing PAO becomes a difficult problem. Its ability to contaminate almost every piece of equipment that it passes through means that a simpler, or just different, analytical technique would be required in order to develop an accurate test for gaseous Poly-alpha olephin. Gas chromatography has shown thus far to be ineffective and has yielded only inconclusive data.

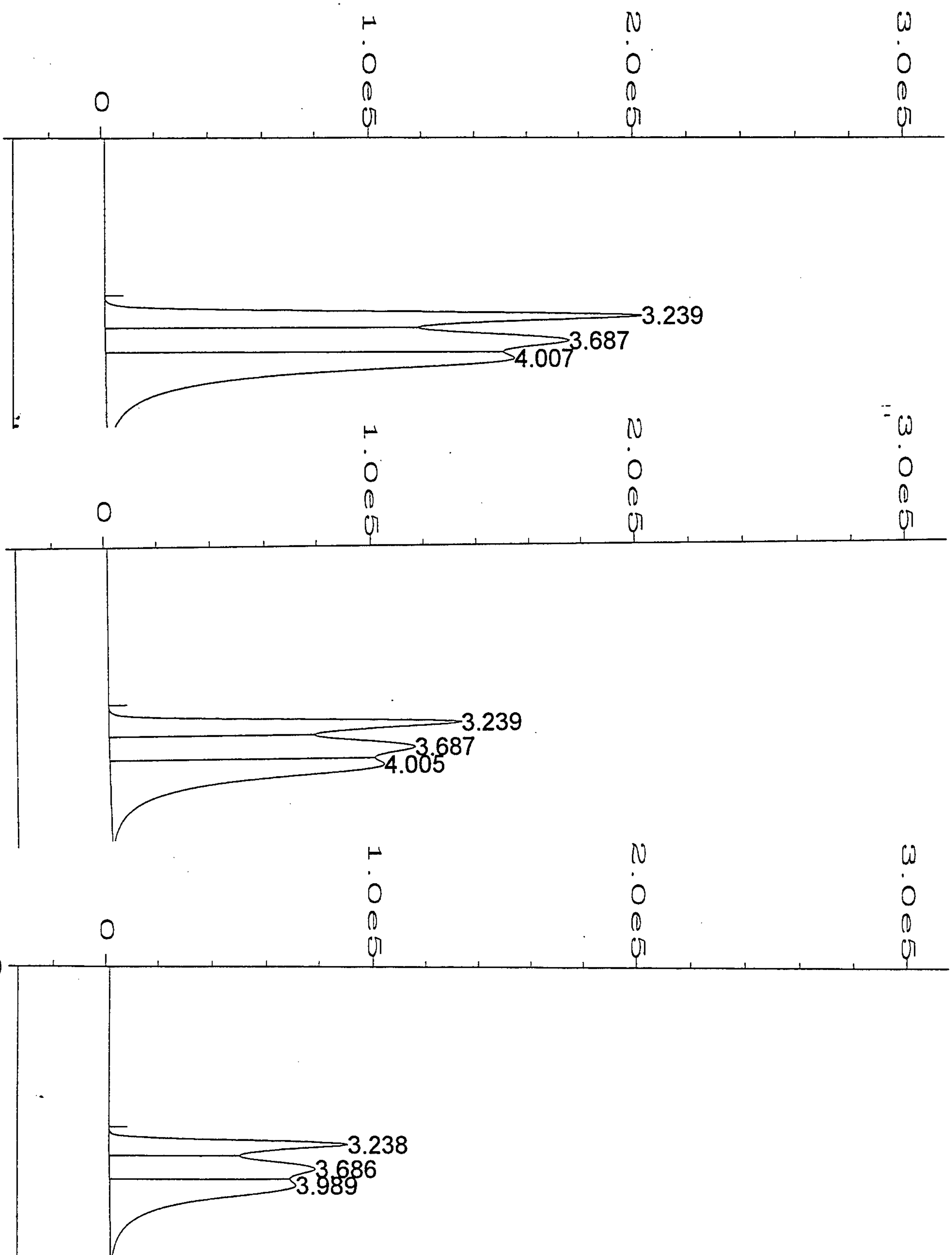

Figure 1

COMPREHENSIVE TESTING FOR THE SELECTION OF AIR FORCE CREW MEMBERS

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Final Report for:

High School Apprentice Program

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August 1996

COMPREHENSIVE TESTING FOR THE SELECTION OF AIR FORCE CREW MEMBERS

Michelle C. Wadsworth
Clark High School

Abstract

The selection of acceptable air force personnel has long been a key element to the overall quality of the accomplishements of the Air Force. This process, however has undertaken au fond constant reconstruction ever since its arrival to the system. The reconstruction currently at hand focuses on the generalization of specific data fields, and their incorporation into the "prediction" of crew performance in those fields. The problem with the specifics of this sort of testing, however, has long been a factor in unreliable test results, and thus, is the focus of the research which is here described. In an effort to supply more general knowledge testing ideals, a series of specific, yet moderately difficult tests has been supplemented, and therefore combined into a single test. This new comprehensive approach to knowledge-testing is the basis of the selection of air force personnel currently under construction. It is with these efforts that the air force can expect to fulfill its accomplishements, and ultimately, itself through the personnel with which it is contrived.

COMPREHENSIVE TESTING FOR THE SELECTION OF AIR FORCE CREW MEMBERS

Michelle C. Wadsworth

<u>Introduction/Discussion of Problem</u>

Knowledge-what is it, and more specifically, how can we test it? This question is the basis for the formation of an accurate predictor test of air force crew member performance. The previous tests used for this purpose have proven to be somewhat too specific in their knowledge scope. These tests focused on minuscule factors of large-scale knowledge bases. Such is the reason for the creation of a more general type of achievement test. Well-rounded knowledge bases prove to be more effective in certain activities. Another added benefit to a more well-rounded general cognitive ability test is the fact that ability directly influences the acquisition of job knowledge. Through the testing of ability, one can also test the future possibilities of the successful acquisition of job knowledge, which can then determine the value of a certain crew member's application of this knowledge. It has been proven that prior job knowledge has almost no influence on subsequent job knowledge, but does, in fact, directly influence the early work sample (Ree, 1995). Also, early work-sample performance strongly influences subsequent work sample performance; whereas, early training job knowledge influences subsequent job knowledge and work-sample performance. (Ree, 1995). These findings prove to be much more than a coincidence. We can deduce that all of the previously, as well as the soon-to-be mentioned factors in job-related functions depend to a great part on general cognitive ability. In other words, the prominent factor in the determination of work-sample performance as well as job-knowledge, all trace back to the basic ability to learn the specifics of a certain job and all of the encompassing factors therein, and to incorporate that information when applicable. In agreement with Hunter (1986), it is believed that "general cognitive ability has high validity predicting performance ratings and training success in all jobs". It is with these findings that I base my more general type of testing method for the prediction of subsequent job knowledge/performance in the multiple fields of which air force crew encounter during the course of their daily decision-making processes.

Methodology

The method for the development of a general test for selection-purposes included primarily a general search of pre-existing achievement/knowledge assessment tests. The validity of job-knowledge tests for many jobs has been demonstrated by Dye, Reck, and McDaniel (1993). They defined job knowledge as "the accumulation of facts, principles, concepts, and other pieces of information that are considered important in the performance of one's job". In their meta-analysis of 502 validity coefficients based on 363,528 individuals, they found a mean validity of .45 for predicting job performance. With such an accumulation in mind, I conducted a thorough search of many Achievement Tests and Measurement Devices, courtesy of the ETS Test Collection Catalog, Vol. 1. Out of more than 14,000 tests and other measurement devices, I narrowed my search to approximately 10 choices, then to 4, and finally to that of DANTES.

DANTES provides the ultimate structure for the general cognitive ability test. Each test focuses primarily on one subject, as did previous air force skill tests. DANTES, however, provides a more general coverage of the individual subjects. This series of tests targets mainly college-age adults, providing a testing of higher-level thinking skills, but simultaneously testing general knowledge of that particular subject. The DANTES program is a series of secured tests administered by postsecondary institutions to grant credit by examination for education gained outside the classroom. Examinations may be worth from two to six credit hours in a baccalaureate program, baccalaureate upper division program, or a technical program. A minimum score for credit has been established by the American Council on Education. Individual institutions administer examinations, as well as set testing schedules.

These instruments compliment the College Board's College Level Examination Program (CLEP) with several instruments in applied technology. They were originally developed for military personnel. Major areas of assessment include mathematics, social science, physical science, business, foreign language, and applied technology. For each test a fact sheet containing the curriculum specifications of the course, a list of texts on which the test is based and statistical information are available. Qualified administrators and faculty may borrow sample tests for a period of 30 days. This instrument is one of a series assessing knowledge in college level social sciences. Knowledge of various aspects of personality and adjustment are assessed. Forms SC and SD are available. ACE recommends granting three semester hours of credit at the baccalaureate level to successful examinees. (ETS Test Collection Catalog, Vol.1). With such features, it is clear as to why these tests provide such an ideal environment for "prediction-type" analysis. Their primary purpose, in fact, is to find out whether an individual is capable of applying the knowledge contained in certain testing subjects to a level satisfactory in "real-world" situations involving this knowledge. For those who are not sure what their cognitive strengths and weaknesses may be, this test can also let them know this; which may ultimately alter the course of their academic/military future.

For these reasons, it was determined that the DANTES tests were to be the model for the shaping of the new air force qualifying test. Once this aspect of the research was distinguished, the method for the usage of these tests was to be evaluated. The next decision was for the computerization of the sample test themselves. A copy of several subject standardized sample DANTES tests (DSSTs) were scanned into the computer and edited for scan-time errors. These tests cover subjects ranging from Introductory College Algebra to Prin of Refrigeration Technology. The particular selection of these tests was determined because of their complimentary conjunction with one another into the entire scheme of the desired testing field. The combination of these particular test provide the ultimate comprehensibility of knowledge with which the air force wishes to test its recruitees. This computerized method of knowledge-testing should ensure the possibility of mass knowledge accumulation, as well as the enhanced analysis thereof. It is with the previous method described that the knowledge-assessment of many individuals will be administered, allowing the successful completion of the entire process currently in
operation.

Results

As to the nature of the particular process at hand, the result of such an extensive study has yet to be determined. The completion of the scanning/editing, and general proofing of these tests has added to the duration of a resulting conclusion. The ultimate result is, therefore, yet to be known as to the effect of the DANTES testing plan. It is hoped, however, that such results will include a more accurate prediction of air force crew performance.

Conclusion

In conclusion, it must be said that, although the results are yet to be revealed, the formatted edition of the comprehensive DANTES test collection holds definite promise for the selection of appropriate air force personnel. The combination of job-knowledge studies, meta-analyses, and many other points of reference, including those mentioned above; all serve as the basis for the selection of the specific DANTES sample tests/study guides and their incorporation into the knowledge-testing device currently under construction. The original use of the DANTES tests for military personnel, combined with the nature of the DANTES test as a broad-knowledge test when used in conjunction with many other DANTES sub-tests; provide the evidence needed to prove this test ideal for the specific goal at hand. The conclusion, therefore; can only be known with the actual application of the methodology described above. The methodological conclusion, however, remains that the involvement of specific interpretations of data such as that described above, can lead only to a successful test in the search for knowledge, and the possible future application thereof. Until that time, we can rely only upon such a conclusion of methodology.

References

ETS Test Collection Catalog. 1986, Vol. 1: Achievement Tests and Measurement Devices. v, 278.

Ree, M.J., Malcom, J., Carretta, T.R., Teachout, M.S. (1995). Role of Ability and Prior Job Knowledge in Complex Training Performance. *Journal of Applied Psychology, 80 (6),* 721-723.

Ree, M.J., Earles, J.A., Teachout, M.S. (1994). Predicting job performance: Not much more than g. *Journal of Applied Psychology, 79 (4),* 518-524.

Besetsny, L.K., Earles, J.A., Ree, M.J. (1993). Little incremental validity for a special test of abstract symbolic reasoning in an Air Force intelligence career field. *Educational and Psychological Measurement, 53 (4),* 993-997.

Carretta, T.R. (1990). Cross validation of experimental USAF pilot training performance models. *Military Psychology, 2 (4),* 257-264.

Besetsny, L.K., Ree, M.J., Earles, J.A. (1993). Special test for computer programmers? Not needed: The predictive efficiency of Electronic Data Processing Test for a sample of Air Force recruits. *Educational and Psychological Measurement, 53 (2),* 507-511.

Sternberg, R.J., Wagner, R.K. (1993). The g-ocentric view of intelligence of job performance is wrong. *Current Directions in Psychological Science, 2 (1),* 1-5.

Sperl, T.C., Ree, M.J., Steuck, K.W. (1992). Armed services vocational aptitude battery and air force officer qualifying test: Analyses of common attributes. *Military Psychology, 4 (3),* 175-188.

Wiskoff, M.F., Rampton, G.M. (Ed). (1989). Military personnel measurement: Testing, assignment, evaluation. 1-211.

Quinones, M.A., Ford, J., K., Teachout, M.S. (1995). The relationship between work experience and job performance: A conceptual and meta-analytic review. Special Issue: Theory and literature. *Personnel Psychology, 48 (4),* 887-910.

THE EFFECT OF HYPERBARIC OXYGENATION ON DU-145 CELLS

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Final Report for:
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Armstrong Laboratory

Sponsored by:
Air Force Office of Scientific Research
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August, 1996

The Effect of Hyperbaric Oxygenation on Du-145 Cells

Elizabeth A. Walker
Theodore Roosevelt High School

Abstract

The effects of hyperbaric oxygenation on Du-145 cells was studied with and without the use of chemotheraputic drug solutions. Du-145 cells were collected then exposed to conditions equivalent to 45 feet below sea level using a hyperbaric chamber or left at sea level as a control. Some of the cells were dosed with solutions of Taxol, Adriamycin, or Cisplatin. The experimental data indicated that hyperbaric oxygenation increased the effects of the Adriamycin on the cancer cells while it showed little effects when used in conjunction with the other two drug solutions.

THE EFFECTS OF HYPERBARIC OXYGENATION ON DU-145 CELLS

Elizabeth A. Walker

Introduction

This experiment focuses on Du-145 cells which are cells from metastatic prostate cancer. The Du-145 cell line is a hearty cell line that can be grown easily in plastic flasks in a temperature controlled incubator.

Hyperbaric oxygenation (HBO) is a treatment which involve:the use of pure oxygen under a controlled pressure to maximize oxygen levels in tissue. HBO is used in emergency conditions such as decompression sickness and carbon monoxide poisoning, as well as in clinical diseases including osteomyelitis, radiation tissue necrosis, and compromised wounds.

Problem

The purpose of this experiment was to test the research value of HBO treatment and to test for possible cancer fighting properties of HBO treatment when used on Du-145 cells.

Methodology

Du-145 cells were grown to 75 percent confluence in Minimum Essential Medium and 10 percent fetal bovine serum (complete MEM) in T-75 flasks. The flasks were then treated with Trypsin-EDTA in order to remove the cells. The Du-145 cells in 10 mL complete medium were then placed in a 50 mL centrifuge tube and spun down for 10 minutes at 2,000 rpm. The supernatant was removed and the cells were resuspended in 3 mL complete medium. Cells were then counted using a hemacytometer. The concentrated cell suspension was then diluted to allow six 96 well plates to be seeded at 6,000 cells per well in 60 wells per plate with 200 uL cell solution in each well. The cells were then allowed to incubate for 24 hours in a temperature controlled incubator.

After the incubation period, the cells bonded to the plastic on the bottom of the 96 well microtiter plates and the medium in the wells was removed using a needle and syringe connected to a pump. The plates were then dosed with solutions containing various dilutions of Taxol, Adriamycin, and Cisplatin, two plates per drug. One plate of each drug was then exposed to hyperbaric oxygenation at the equivalent depth of 45 feet below sea level for 3 hours. The 3 remaining plates were left at room temperature under sterile conditions while the dive occurred.

After the 3 hours of treatment, the cells were washed 3 times with phosphate buffered saline and the placed in 200 uL of complete medium per well. The cells were then allowed to incubate at 37 degrees Celsius for 96 hours. Fifty uL of 50 percent trichloroacetic acid (TCA) was then added to each well and the plates were then placed in the refrigerator for 1 hour. The plates were then washed five times with tap water. The excess water was shaken out and 50 uL of SRB dye was added. The plates then stayed at room temperature for 10 minutes for dye absorption. The plates were then washed 5 times with 1 percent acetic acid, shaken out, and allowed to dry overnight with the lids off. After the drying was complete, 200 uL Tris-base was added and the plates were read at 492 nm in the plate reader.

Results

Three experiments were completed using well plates seeded at 6,000 cells per well. The plate reader showed the highest absorbency rates to be in the cells treated with Adriamycin and exposed to HBO. All other plates showed minimal changes when compare to the controls.

Conclusion

This initial experiment has shown that HBO may increase the cancer fighting ability of Adriamycin. More experiments of this nature should be performed to demonstrate reproducibility of the results.

This experiment does demonstrate that HBO could be a very beneficial factor in the treatment of prostate cancer when used in conjunction with Adriamycin..

References

The knowledge and experience attained in the eight weeks of study can attributed to the wonderful assistance and training from the great staff at AL/AOH, especially Dr. Larry Krock, Dr. John Kalns, and Dr. Edward Piepmeier.

SWIPE METHOD DEVELOPMENT FOR THE TRACE ANALYSIS OF UNICHARGE (M231 and M232) COMPONENTS IN COTTON GAUZE EXTRACTS USING HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC) WITH AN ULTRAVIOLET DETECTOR (UV)

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Final Report for:
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Sponsored by:
Air Force Office of Scientific Research
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August 1996

LIST OF ABRREVIATIONS AND THEIR MATCHING TERMS

HPLC-UV: High Performance Liquid Chromatography

NGL: Nitroglycerin

NGG: Nitroguanidine

4ABP: 4-Aminobiphenyl

BPA: Biphenylamine

DNT: Dinitrotoluene

DBP: Dibutylphthalate

MeOH: HPLC-UV grade methanol

EtOH: HPLC-UV grade ethanol

H_2O: De-ionized water (Nanopure®)

ug: microgram

ml: milliliter

nm: nanometer

LIST OF CHEMICAL STANDARDS

Nitroglycerin: 100ug/ml in EtOH

Nitroguanidine: 100ug/ml in MeOH

4-Aminobiphenyl: 500ug/ml in MeOH

Biphenylamine: 500ug/ml in MeOH

Dibutylphthalate: 1000ug/ml in MeOH

2,3 & 2,4 & 2,6 & 3,4-Dinitrotoluene: 1000ug/ml in MeOH

SWIPE METHOD DEVELOPMENT FOR THE TRACE ANALYSIS OF UNICHARGE (M231 and M232) COMPONENTS IN COTTON GAUZE EXTRACTS USING HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC) WITH AN ULTRAVIOLET DETECTOR (UV)

Mollie L. Webb
Kettering-Fairmont H.S.

Abstract

Methods were developed to collect the trace compounds from the unicharge (M231 and M232) outer shell casings and for the analysis of those compounds with the use of high-performance liquid chromatography. The trace compounds include nitroglycerin, nitroguanidine, dibutylphthalate, diphenylamine, 4-aminobiphenyl, 2,3-dinitrotoluene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, and 3,4-dinitrotoluene. These methods were developed for stored unicharge shells where the samples would have to be transferred back to the laboratory for analysis. Swiping the outer shell casings provided the surface concentration of the trace compounds for a dermal hazard assessment of the unicharge. Sample analyses indicate that there is a hazardous amount of the trace elements on the surface of each unicharge casing. However, the rate of dermal penetration into human skin has not yet been determined.

SWIPE METHOD DEVELOPMENT FOR THE TRACE ANALYSIS OF UNICHARGE (M231 and M232) COMPONENTS IN COTTON GAUZE EXTRACTS USING HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC) WITH AN ULTRAVIOLET DETECTOR (UV)

Mollie L. Webb

Introduction

The unicharge (M231 and M232) is a solid propellant used to replace the 155 mm cannon propellant. It was created so that when discharged from the modular artillery charge unit there would be little to no ash left in the chamber. The shell casing mainly consists of nitrocellulose which burns up almost completely when the charge is applied. Nitrocellulose does not cause a dermal hazard to humans in this case therefore it is not considered in this method development.

It became necessary to study the shell casings of the unicharge because workers who were handling them were experiencing headaches after a prolonged period of exposure. Therefore, the dermal hazard of the unicharge propellant was to be evaluated by two subdivisions, the first one being the surface concentration of the trace compounds on the outer shell casing of the unicharge and the second being the penetration rate of these compounds through the skin. It is feasible that the primary dermal hazard would be a solid or gummy residue on the surface of the unicharge where both palms and hands and possibly both forearms would be exposed. It was possible to make a primary assessment of the hazard based on nitroglycerin which composes about 22.5% of the unicharge. Used pharmaceutically to treat angina, nitroglycerin has been determined to cause severe headaches with occupational exposure and a severe allergic skin reaction with dermal exposure. It is possible to get more than a safe dose of nitroglycerin in less than one hour (Kikkoji 1235). As for the other compounds, no information on the dermal penetration could be found. Therefore, it became necessary to analyze cotton gauze swipes taken from the unicharge to determine the concentration of the trace compounds on the surface of each M231 and M232 shells and assess their dermal hazard.

Discussion of Problem

Swipes had to be taken from unicharge shells located in Yuma, Arizona. Therefore, a method needed to be developed in which the swipes could be taken and transported back to Dayton, Ohio without leakage, loss of sample, or contamination. The swipes then had to be analyzed at the laboratory so a method of analysis also had to be determined.

Methodology

The unicharge swipe method involves the use of centrifuge tubes, gauze, and methanol. The gauze was placed in the centrifuge tube and 5mL of methanol was added. The area of the unicharge to be swiped was marked off, the gauze was removed from the tube, and then it was wiped across the marked area. The gauze was then placed back into the tube and sealed tightly with a screw cap. The finished swipes were boxed up and sent back to Dayton, Ohio. Upon arrival, the methanol was removed from of the centrifuge tube by means of an evaporator equipped with nitrogen. The gauze in the centrifuge tube was then reconstituted in 5mL of methanol. Samples were drawn form the tube and placed into vials for analysis on the HPLC-UV.

The method to identify the components of the unicharge on the HPLC-UV was also developed. The UV Spectrophotometer with two 10 mm black-blue quartz cells was used to determine at what wavelength the components absorb UV light so that the HPLC-UV could be set to find the components at that wavelength. For each component, a series dilution (see figure 1.1) was done from the chemical standard using the equation, $V_1C_1 = V_2C_2$ where V_1 is the variable indicating the volume of the solvent necessary for the dilution, C_1 is the higher concentration, V_2 is the total volume for the new solution, and C_2 is the diluted concentration, therefore, $V_1 = V_2 C_2 / C_1$.

Figure 1.1

For 10ug/mL NGL in H_2O, V_1 = (3ml)(10ug/mL) / (100ug/mL)

V_1 = 0.3ml of 100ug/mL NGL
2.7ml of H_2O

Figure 1.1 (cont.)

Series Dilution for Nitroglycerin in H_2O for Run 1

Wanted Conc.	mL previous Conc.	mL H_2O	total mL
7.5ug/mL	1.5	0.5	2
5.0ug/mL	1	0.5	1.5
2.5ug/mL	1	1	2
1.0ug/mL	1.2	1.8	2
0.75ug/mL	1.5	0.5	2
0.50ug/mL	1	0.5	1.5
0.25ug/mL	1	1	2
0.01ug/mL	0.08	1.92	2

By running the wavelength scan for each compound at different concentrations, it is able to be determined if there is a concentration at which the UV light does not appear to be absorbed. The analyst then will know not to run the compound at that concentration on the HPLC-UV since the compound will not appear. This usually occurs when the concentration is very small.

By setting the UV Spectrophotometer to scan at different wavelengths, it is possible to determine at which point the compound absorbs the UV light. When running the samples, it is first necessary to run a blank. Whatever the compound is diluted in, is usually what it is run against, but in this case it is also appropriate to run the sample against air. The compound sample is always run after the blank, and a difference graph is created (the blank graph is compared against the compound graph). If a valley or peak appear, then it is safe to say that UV light absorption has occurred. At the points where the graph peaks or valleys are wavelengths and absorption numbers. Therefore, the chart next to the graph gives the highest peaks and valleys in numerical order (see figures 1.2 - 1. 4).

After the series dilution and the UV Spectrophotometer runs, a graph of nitroglycerin's concentrations was plotted versus its matching absorbency of UV light as to identify any linearity between the decreasing concentrations and their absorbency of UV light. The hypothesis was that as the concentration began to decrease the absorbency would also decrease linearly with it (see figures 1.5 - 1.7).

Figure 1.2

H2O vs. H2O + 10ug/ml NGL

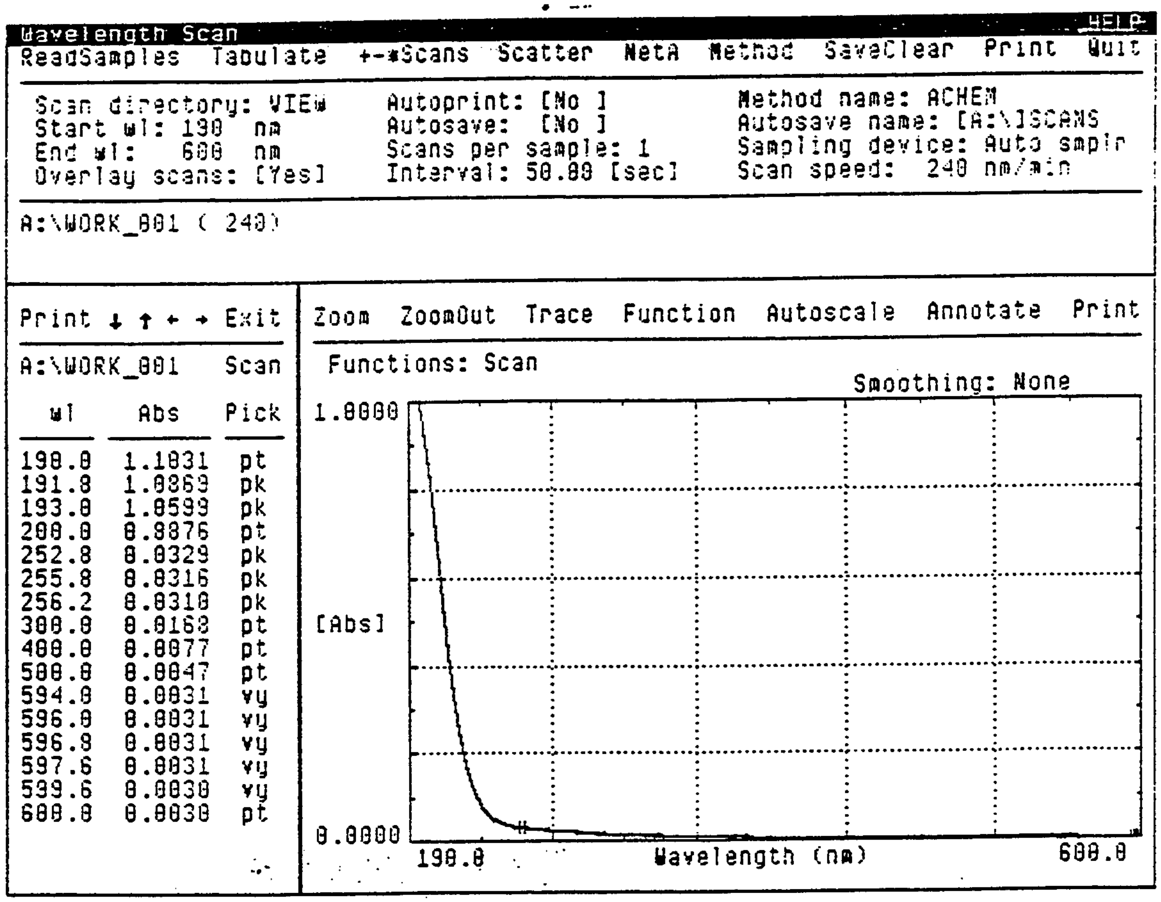


Figure 1.3

Air vs. 50:50 MeOH:H2O + 10ug/ml NGG

```
Wavelength Scan                                                                    HELP
ReadSamples  Tabulate  +-*Scans  Scatter  MetA  Method  SaveClear  Print  Quit

 Scan directory: VIEW       Autoprint: [No ]        Method name: ACHEM
 Start wl: 198  nm          Autosave:  [No ]        Autosave name: [A:\]SCANS
 End wl:   688  nm          Scans per sample: 1     Sampling device: Auto smplr
 Overlay scans: [No ]       Interval: 58.88 [sec]   Scan speed:  688 nm/min

 A:\WORK_881 ( 688)

Print ↓ ↑ ← → Exit     Zoom  ZoomOut  Trace  Function  Autoscale  Annotate  Print
A:\WORK_881   Scan      Functions: Scan
                                                       Smoothing: None
  wl      Abs    Pick
```

wl	Abs	Pick
198.5	3.4859	pk
288.8	8.8387	pt
212.8	8.7422	pk
264.8	1.7193	pk
388.8	8.8968	pt
351.5	-8.8242	pk
354.5	-8.8247	pk
374.5	-8.8275	vy
379.8	-8.8277	vy
385.8	-8.8275	vy
392.5	-8.8276	vy
394.8	-8.8274	vy
488.8	-8.8272	pt
588.8	-8.8268	pt
688.8	-8.8259	pt

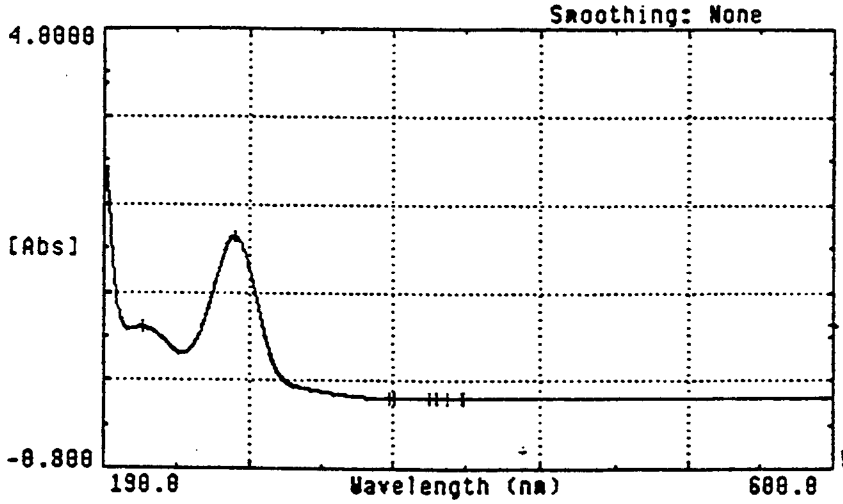


Figure 1.4

EtOH vs. EtOH + 1.0ug/ml NGL

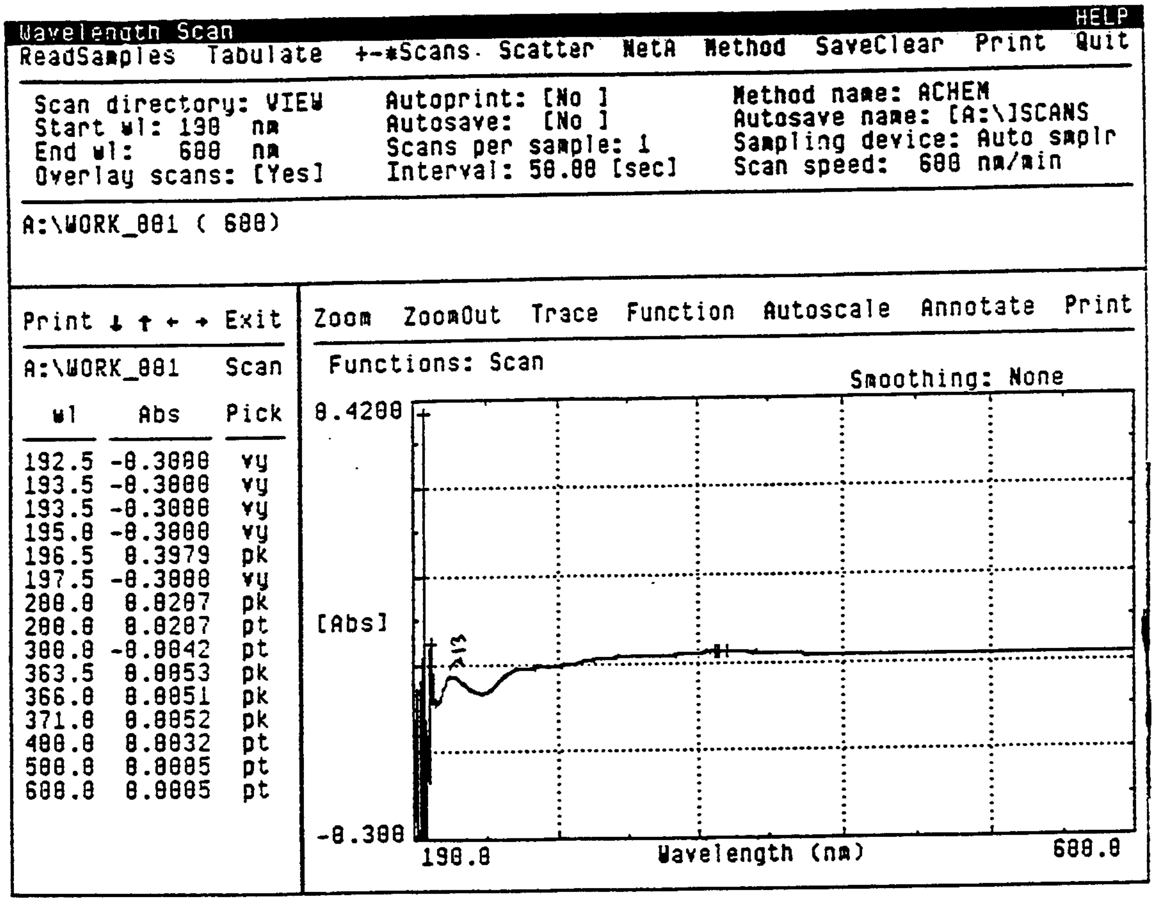


Figure 1.6

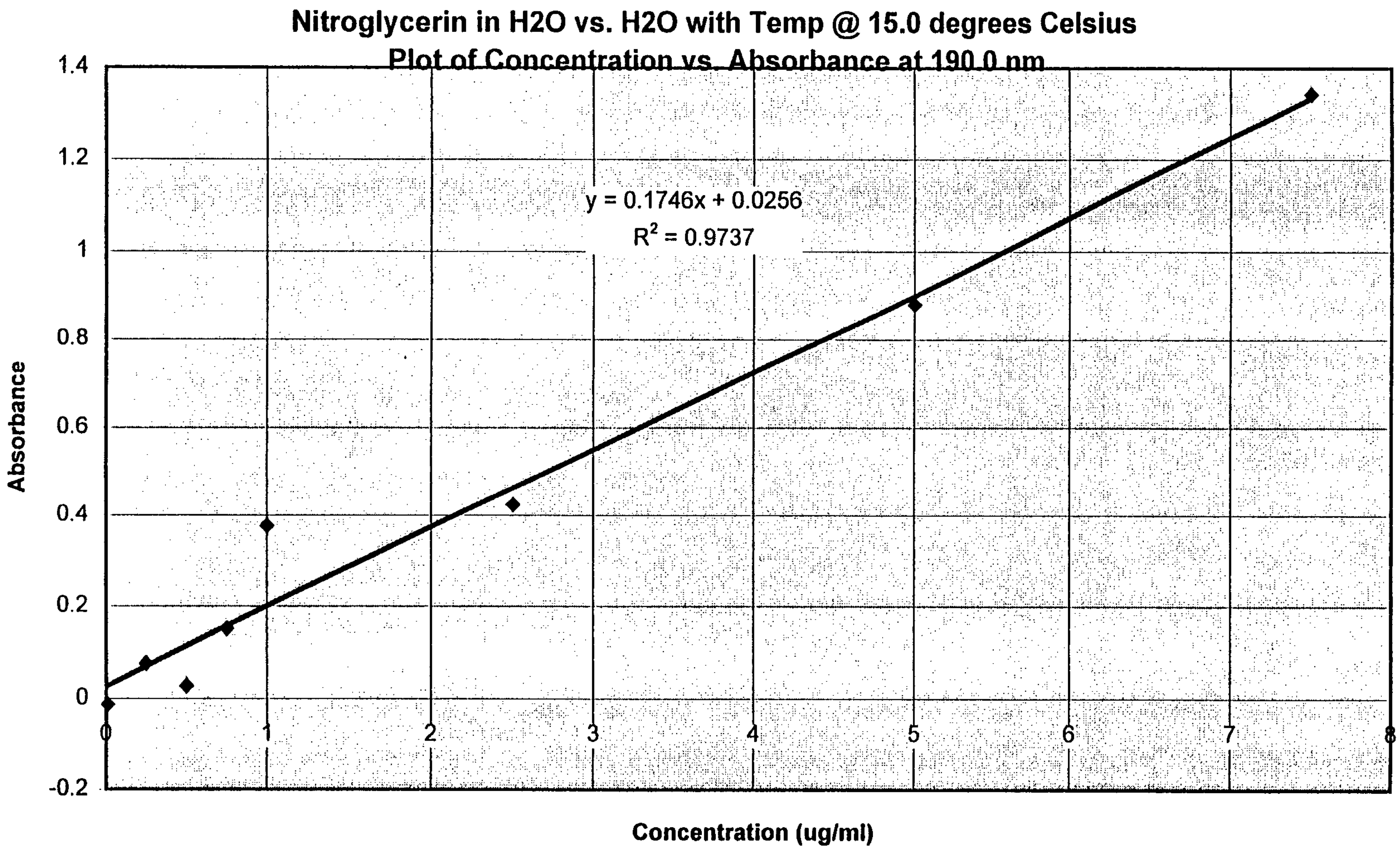

Nitroglycerin in H2O vs. H2O with Temp @ 15.0 degrees Celsius
Plot of Concentration vs. Absorbance at 190.0 nm
y = 0.1746x + 0.0256
R2 = 0.9737
Absorbance
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
1
2
3
4
5
6
7
8
Concentration (ug/ml)

Figure 1.7

Nitroglycerin in H2O vs H2O with Temp. @ 15.0 degrees Celsius
Plot of Concentration vs. Absorbance at 200.0 nm

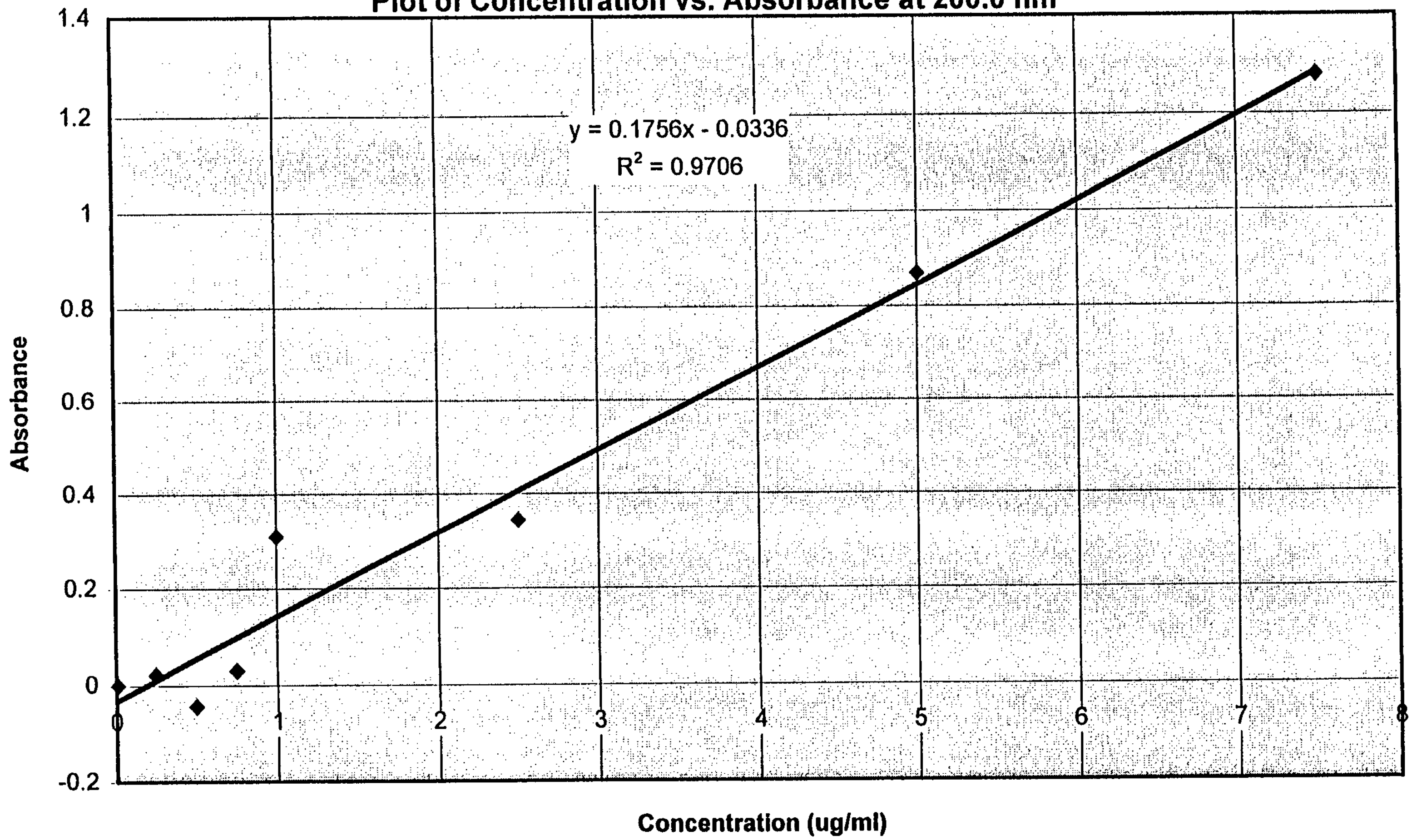


Figure 1.5

Run 2 of Nitroglycerin in H2O vs. H2O with Temp. at 15.0 degrees Celsius

Filename	Concentration (ug/mL)	Abs at 190.0nm	Abs at 200.0 nm	
NGW1	10	1.1031	0.8876	not on chart
NGW2	7.5	1.3435	1.2784	
NGW3	5	0.8794	0.8692	
NGW4	2.5	0.424	0.3438	
NGW5	1	0.3764	0.3087	
NGW6	0.75	0.15	0.0302	
NGW7	0.5	0.027	-0.0446	
NGW8	0.25	0.0752	0.0216	
NGW9	0.01	-0.0133	-0.0009	

This hypothesis only holds true for nitroglycerin in H_2O.

Once an approximate wavelength has been found for a component, that component is run on the HPLC-UV as a control sample (for standard operating procedure of the HPLC-UV see Pollard 1-3). As the components are run separately through the HPLC-UV for the control sample, it is necessary to observe at what time they come out of the column (called retention time). When the components are run as one sample, it will be necessary to know them apart. This is accomplished by the retention time for each individual component. Each component has its own retention time, therefore the components can be distinguished from one another.

Control swipes of the unicharge components must also be run as to determine the proper mobile phase. The mobile phase is what keeps the components from coming out of the column at the same time on the HPLC-UV. The mobile phase is chemical dependent. For the unicharge components, methanol and Nanopure@ water are used in a ratio of 68:32 respectively. This ensures proper peak separation for identification of the unicharge components.

The components are identified on the HPLC-UV, and the peak area is measured for each component (see figure 1.8). From this measurement, the concentration of the components in each

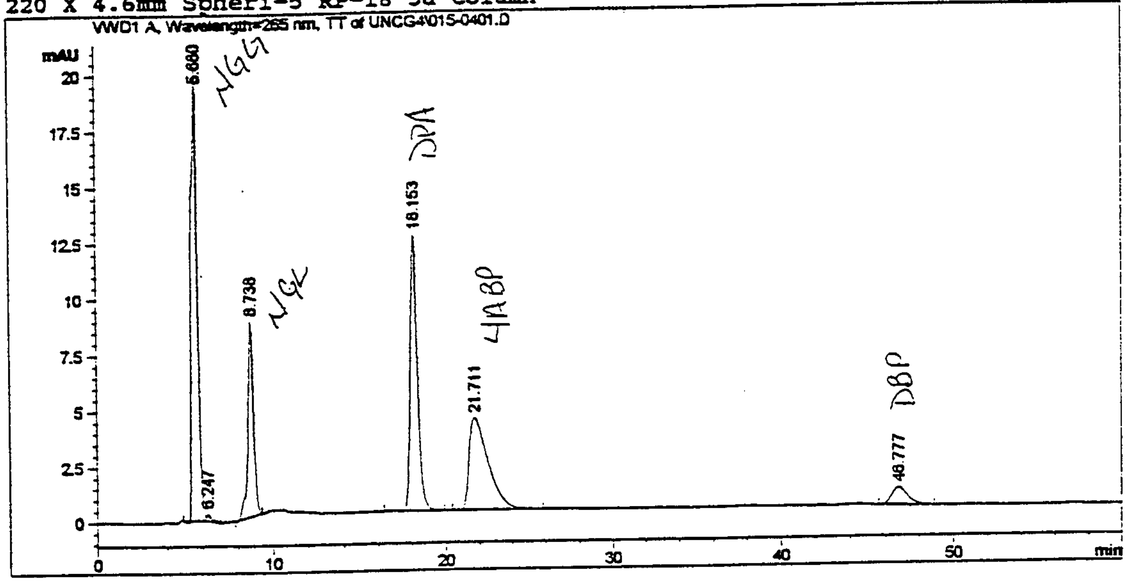
Figure 1.8

Data File c:\hpchem\1\data\UNCG4\~~015-0401~~.D Sample Name: AccolStd3.0ug/ml

271-0101 03 Aug 96 David Pollard

Acq. Method	: DAN7.M	Seq. Line	: 4
Acq. Operator	: DLP	Vial	: 15
Injection Date	: 8/3/96 3:54:30 PM	Inj	: 1
Sample Name	: AccolStd3.0ug/ml	Inj Volume	: 10 µl

Sequence File : C:\HPCHEM\1\SEQUENCE\DAN7.S
Analysis Method : C:\HPCHEM\1\METHODS\DAN7.M
220 X 4.6mm Spheri-5 RP-18 5u Column



Area Percent Report

Sorted by Signal
Multiplier : 1.000000

Signal 1: VWD1 A, Wavelength=265 nm, TT

Peak #	RT [min]	Type	Width [min]	Area [mAU*sec]	Height [mAU]	Area %
1	5.680	BH	0.323	470.49091	20.36897	33.1618
2	6.247	HV	0.343	7.09032	3.44436e-1	0.4997
3	8.314	Fsho	0.000	0.00000	9.55059e-1	0.0000
4	8.738	PBA	0.333	196.14378	8.76980	13.8249
5	18.153	BB	0.445	362.25333	12.37563	25.5328
6	21.711	BV	1.188	330.14960	4.12645	23.2700
7	24.089	Rsho	0.000	0.00000	1.13230e-1	0.0000
8	46.777	VV	1.006	52.64777	7.89684e-1	3.7108
Totals :				1418.77576	47.84327	

HP LC System Saturday, August 03, 1996 4:55:11 PM by DLP Page 1 of 1 centrifuge tube sample is determined. The concentration in the sample indicates the concentration on the surface of the unicharge shell casing.

Results

The surface concentration was determined for only four of the unicharge components because the other components did not appear to permeate through the shell casing to the outer surface. The four components included: nitroglycerin, nitroguanidine, 4-aminobiphenyl, and biphenylamine.

The results are listed in figures 1.9 - 2.3. At the bottom of figures 2.0 - 2.3, the graphs give a comparison between the control samples and the field samples. They show the linearity between the compounds.

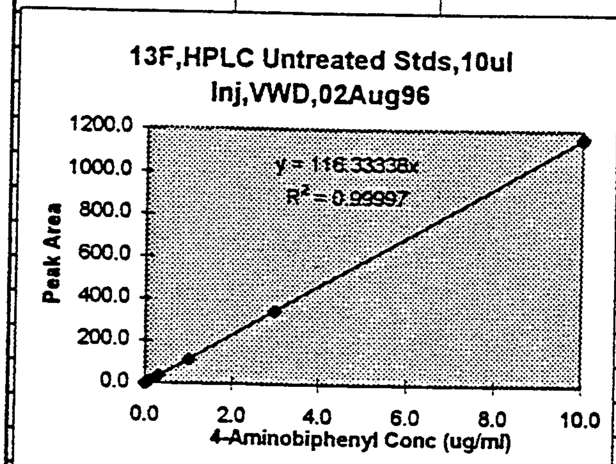
Conclusions

The unicharge presents a health hazard to anyone that comes in contact with it. Precautionary measures should be taken when handling the loaded shells such as protective gloves and clothing and eye protection. Human skin should not come in contact with the shell. The penetration rate into human skin still needs to be determined to make a complete hazard assessment for humans.

13F, 25July96, Shell Swipe Results						
Sample	Nitroglycerin, MDL 0.096ug/ml			Diphenylamine, MDL 0.026ug/ml		
#.Shell.Cartridge.Quarter.Wipe	Peak Area	Conc(ug/ml)	x15ml=ug	Peak Area	Conc(ug/ml)	x15ml=ug
1.XM231.1.1.1	241.0	4.08	61.2	346.3	2.85	42.8
2.XM231.1.1.2	144.0	2.44	36.5	237.8	1.96	29.4
3.XM231.1.2.1	131.8	2.23	33.5	248.3	2.04	30.7
4.XM231.1.2.2	154.6	2.62	39.2	339.1	2.79	41.9
5.XM231.2.1.1	253.4	4.29	64.3	436.2	3.59	53.9
6.XM231.2.1.2	186.5	3.16	47.3	392.8	3.23	48.5
7.XM231.2.2.1	394.3	6.67	100.1	424.8	3.50	52.5
8.XM231.2.2.2	178.6	3.02	45.3	192.0	1.58	23.7
9.XM231.3.1.1	258.5	4.37	65.6	368.1	3.03	45.5
10.XM231.3.1.2	219.6	3.72	55.7	344.5	2.84	42.5
11.XM231.3.2.1	306.8	5.19	77.9	454.7	3.74	56.2
12.XM231.3.2.2	183.5	3.10	46.6	311.1	2.56	38.4
13.XM232.1.1.1	1838.9	31.12	466.7	817.7	6.73	101.0
14.XM232.1.1.2	1396.5	23.63	354.4	747.8	6.16	92.4
15.XM232.1.2.1	2132.2	36.08	541.2	822.7	6.77	101.6
16.XM232.1.2.2	1323.8	22.40	336.0	123.2	1.01	[illegible] 86.5
17.XM232.2.1.1(2 AccoladePads)	474.7	8.03	120.5	275.0	2.26	34.0
18.XM232.2.1.2	1246.4	21.09	316.3	730.3	6.01	90.2
19.XM232.2.2.1	1626.5	27.52	412.8	772.5	6.36	95.4
20.XM232.2.2.2	1262.7	21.37	320.5	769.2	6.33	95.0
21.XM232.3.1.1	1785.0	30.20	453.0	604.6	4.98	74.7
22.XM232.3.1.2	1905.2	32.24	483.6	821.1	6.76	101.4
23.XM232.3.2.1	2117.4	35.83	537.4	747.2	6.15	92.3
24.XM232.3.2.2	2078.2	35.16	527.5	958.0	7.89	118.3
25 Methanol Blank	17.4	0.29	4.4	0.0	0.00	0.0
26 Methanol/Accolade Blank	8.0	0.14	2.0	0.0	0.00	0.0
27 Methanol/Accolade Blank	4.5	0.08	1.1	0.0	0.00	0.0
Dayton Methanol Blank	25.9	0.44	6.6	0.0	0.00	0.0
Dayton Methanol Blank	19.7	0.33	5.0	0.0	0.00	0.0
Dayton Methanol/Accolade Blank	0.0	0.00	0.0	0.0	0.00	0.0
Dayton Methanol/Accolade Blank	0.0	0.00	0.0	0.0	0.00	0.0
Dayton Standard 0.0667ug/ml	7.0	0.12	1.8	5.9	0.05	0.7
Dayton Standard 0.0667ug/ml	8.2	0.14	2.1	5.8	0.05	0.7
Dayton Standard 0.133ug/ml	6.7	0.11	1.7	12.7	0.10	1.6
Dayton Standard 0.133ug/ml	7.9	0.13	2.0	12.4	0.10	1.5
Control	Peak Area	Conc(ug/ml)	x2ml=ug	Peak Area	Conc(ug/ml)	x2ml=ug
231 Green Shell Blank (2sq.in.)	895.6	15.15	30.3	2897.7	23.86	47.7
23 Brown Shell Blank (2sq.in.)	31.6	0.53	1.1	1129.8	9.30	18.6
Unpainted Shell Blank (4sq.in.)	30.7	0.52	1.0	764.2	6.29	12.6
deactivated	0	0	0	0	0	0
Nitroguanidine(MDL 0.021ug/ml) not detected.						
4-Aminobiphenyl(MDL 0.048ug/ml) not detected.						
Dibutylphthalate(MDL 0.162ug/ml) not detected.			Shell XM231 Quarter Area = 43.8sq.in			
MDL = Method Detection Limit			Shell XM232 Quarter Area = 43.0sq.in			

Figure 1.9

4-Aminobiphenyl Standards			
	Std Solution Untreated	Vortex With Accolade Pad	Accolade /
Conc(ug/ml)	Peak Area	Peak Area	Untreated Std
0.0	0.0	0.0	
0.0	0.0	0.0	
0.1	11.7	10.8	0.92
0.1	12.5	11.1	0.89
0.3	36.6	33.0	0.90
0.3	34.7	33.3	0.96
1.0	115.7	106.6	0.92
1.0	115.6	106.0	0.92
1.0		106.5	
1.0		107.5	
1.0		109.2	
1.0		110.3	
1.0		109.0	
3.0	346.5	330.1	0.95
3.0	345.0	330.1	0.96
10.0	1160.2	1128.3	0.97
10.0	1168.5	1129.1	0.97
1ug/mlSamples			
Mean		107.9	0.94
StDev		1.637	0.029
StDev/Mean		0.015	
t-Test		3.143	
MDL(ug/ml)		0.048	



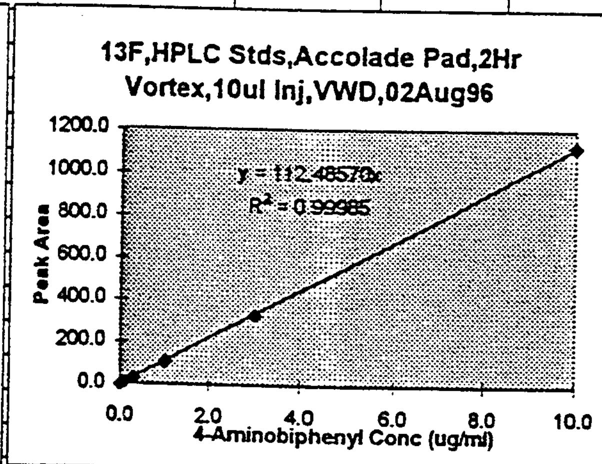
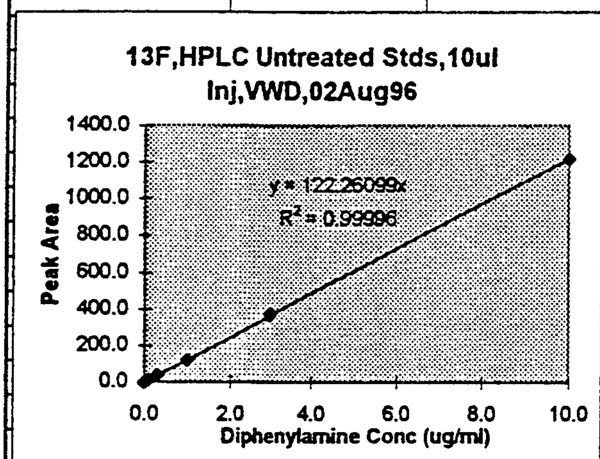
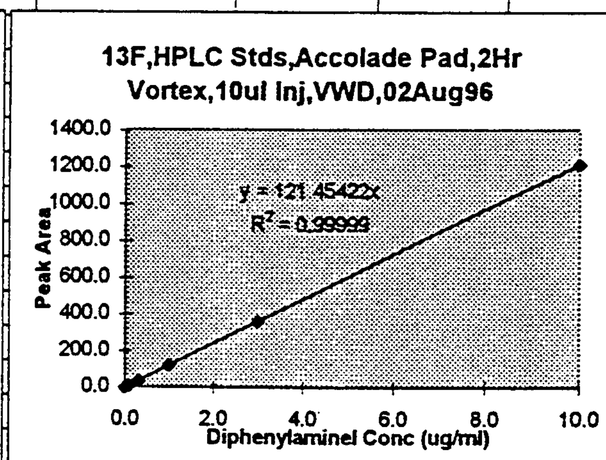


Figure 2.0

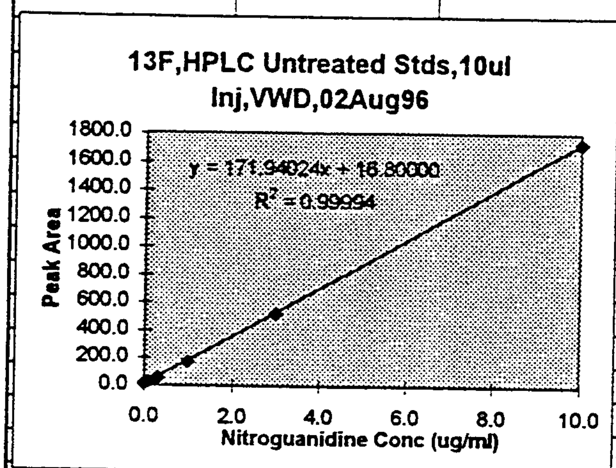
Figure 2.1

Diphenylamine Standards			
	Std Solution	Vortex With	
	Untreated	Accolade Pad	Accolade /
Conc(ug/ml)	Peak Area	Peak Area	Untreated Std
0.0	0.0	0.0	
0.0	0.0	0.0	
0.1	12.7	11.9	0.94
0.1	12.9	12.0	0.93
0.3	36.9	37.0	1.00
0.3	36.8	36.0	0.98
1.0	122.5	119.9	0.98
1.0	122.9	119.3	0.97
1.0		118.8	
1.0		119.4	
1.0		121.1	
1.0		120.7	
1.0		121.3	
3.0	368.3	362.3	0.98
3.0	376.3	363.6	0.97
10.0	1220.8	1215.4	1.00
10.0	1221.0	1215.5	1.00
1ug/mlSamples			
Mean		120.1	0.97
StDev		0.971	0.024
StDev/Mean		0.008	
t-Test		3.143	
MDL(ug/ml)		0.025	





	Nitroguanidine Standards					
	Std Solution	Vortex With				
	Untreated	Accolade Pad	Accolade /			
Conc(ug/ml)	Peak Area	Peak Area	Untreated Std			
0.0	16.7	16.7				
0.0	16.9	17.1				
0.1	31.2	29.8	0.96			
0.1	31.1	29.8	0.96			
0.3	61.7	55.7	0.90			
0.3	61.8	56.7	0.92			
1.0	181.2	164.9	0.91			
1.0	181.4	162.8	0.90			
1.0		162.7				
1.0		164.8				
1.0		163.9				
1.0		165.4				
1.0		163.4				
3.0	527.0	470.5	0.89			
3.0	527.4	470.4	0.89			
10.0	1738.3	1584.6	0.91			
10.0	1739.3	1559.4	0.90			
1ug/mlSamples						
Mean		164.0	0.91			
StDev		1.073	0.024			
StDev/Mean		0.007				
t-Test		3.143				
MDL(ug/ml)		0.021				



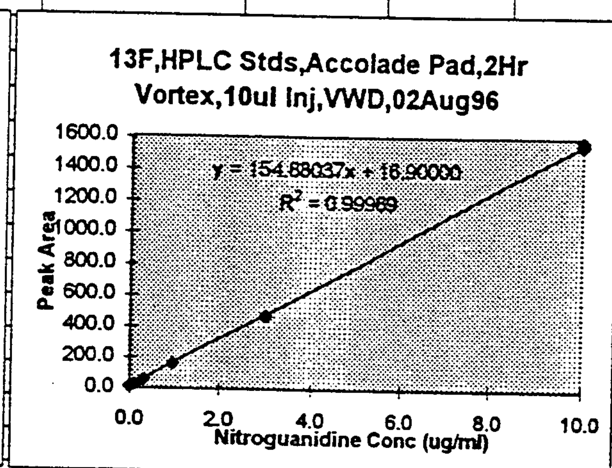
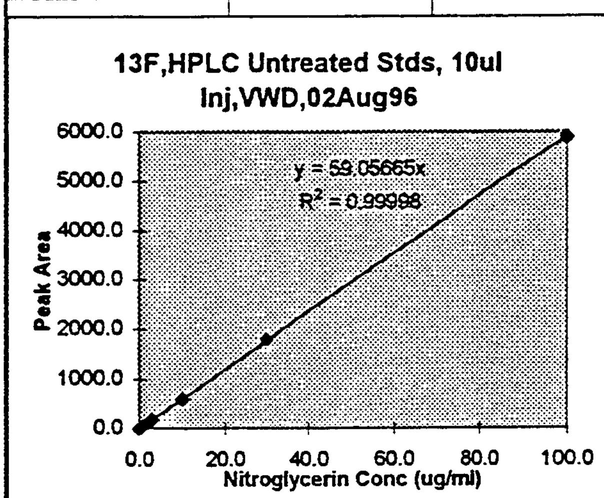
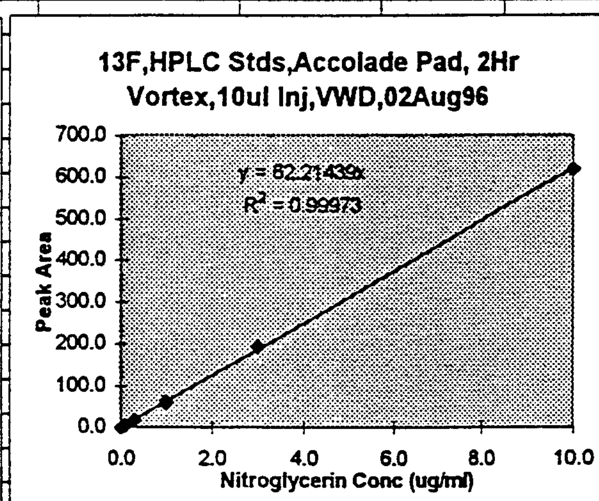


Figure 2.2

Figure 2.3

Nitroglycerin Standards			
	Std Solution Untreated	Vortex With Accolade Pad	Accolade /
Conc(ug/ml)	Peak Area	Peak Area	Untreated Std
0.0	0.0	0.0	
0.0	0.0	0.0	
0.1	9.8	4.2	0.43
0.1	10.7	6.8	0.64
0.3	18.4	19.7	1.07
0.3	16.4	17.9	1.09
1.0	61.3	62.8	1.02
1.0	67.6	61.8	0.91
1.0		58.3	
1.0		63.8	
1.0		63.7	
1.0		63.3	
1.0		62.2	
3.0	182.5	196.1	1.07
3.0	185.8	192.7	1.04
10.0	594.3	620.8	1.04
10.0	597.9	618.8	1.03
30.0	1795.0		
100.0	5889.4		
100.0	5913.3		
1ug/mlSamples			
Mean		62.3	0.94
StDev		1.902	0.078
StDev/Mean		0.031	
t-Test		3.143	
MDL(ug/ml)		0.096	





Cerebral Oxygen Levels as a Psychophysiological Measure of Pilot Workload

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Armstrong Laboratory

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and

Armstrong Laboratory

September 1996

CEREBRAL OXYGEN LEVELS AS A PSYCHOPHYSIOLOGICAL MEASURE OF PILOT WORKLOAD

Eric Yu

Abstract

Cerebral oxygen levels were monitored during simulated tracking tasks in a full F-16 fighter cockpit mockup. The tracking task became increasingly difficult for each of three data collection runs to induce a physiological response in cerebral tissue oxygen saturation. Pre- and post-baseline data was gathered with subjects' eyes open or closed, alternated between runs. Correlation was established between flight activity and cerebral oxygen levels but could not be reliably confirmed. Pre- and post-baseline data had no significant difference between having subjects' eyes open or closed.

CEREBRAL OXYGEN LEVELS AS A PSYCHOPHYSIOLOGICAL MEASURE OF PILOT WORKLOAD

Eric Yu

Introduction / Discussion of Problem

Assessing pilot mental workload has become increasingly important in the military, as technological breakthroughs increase the demand on pilots in performing their mission. Physiological characteristics have been seen as a reliable indicator of mental workload, and many studies have focused upon heart rate. Jorna (3.) established a reliable degree of heart rate variability in differing degrees of workload demand. Lindolm et. al. (4.) and Roscoe (5.) also reached reliable conclusions through varied procedures that heart rate is a consistent indicator of mental workload. A study by Fulton (2.) focused upon a tumor and associated bruit in the occipital lobe of a patient's brain, interfering with visual activity. When the patient was subjected to visual stimuli, the bruit increased remarkably. When the patient's eyes were closed, the bruit decreased. These studies help to link vascular activity to mental activities and mental workload. However, there have been no studies within the last ten years on the oxygen levels of the cerebrum, the portion of the brain responsible for thought and reason.

This study focuses upon the vascular activity of cerebral tissue by measuring the levels of oxygen saturation, providing an index of blood flow.

As a supplemental study, the experiment includes a procedure to help address a debate within research: whether pre- and post-baseline data of subjects should be collected with the eyes open or closed.

Method

Two male and two female active Air Force personnel volunteered to be trained in a full mockup of an F-16 cockpit. Test subjects were trained to read the information presented by the instrument panels and heads-up display, operate the throttle and air brakes, and perform simulated low- and high-G flight maneuvers. Actual flight dynamics of the F-16 were incorporated into the control algorithm of the simulation. A computer-generated view of the exterior landscape and target plane was projected from an Electrohome ECP 2000

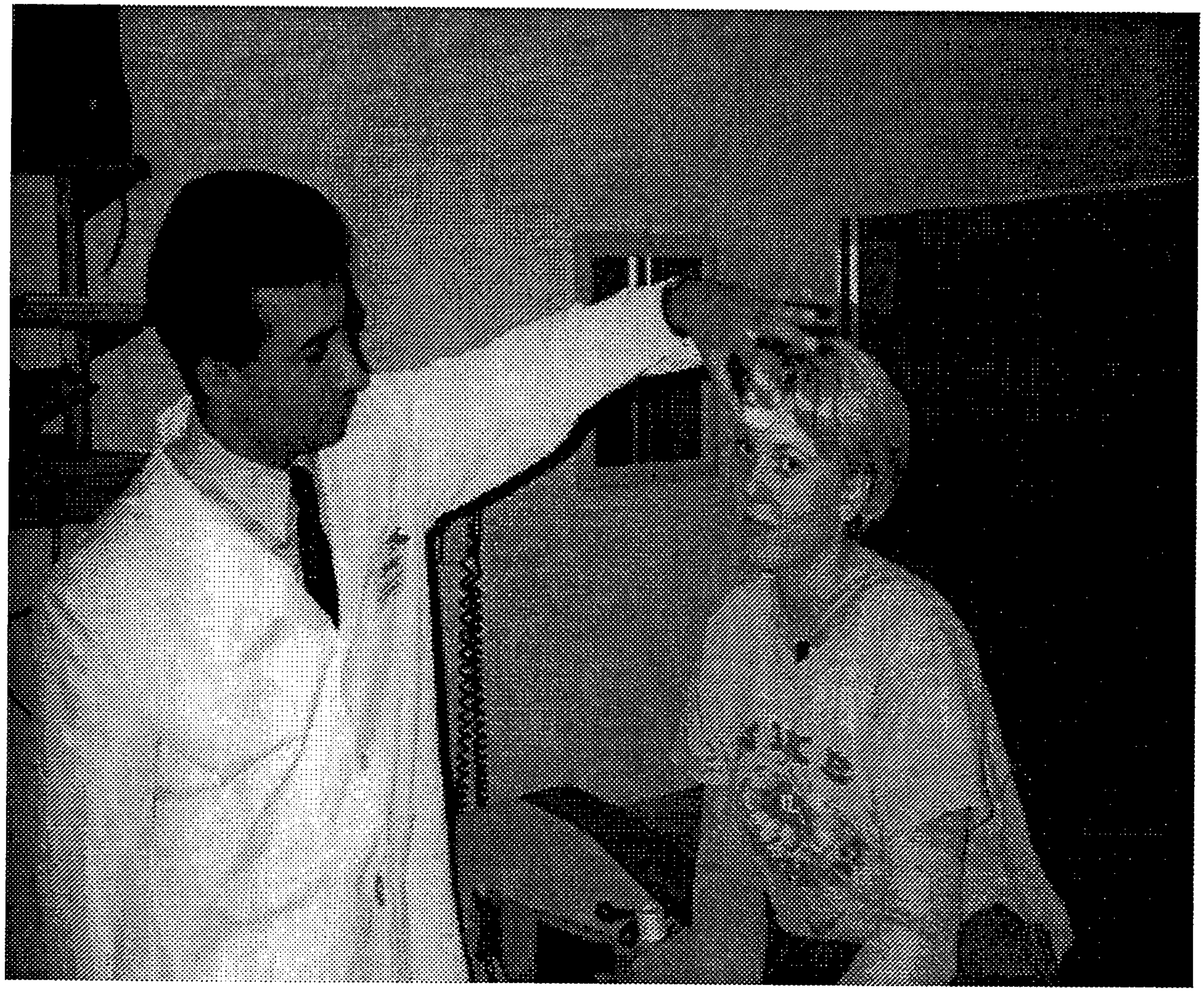


Figure 1. Somanetics cerebral tissue oxygen sensor

Overhead Projector onto a white 50-inch-by-90-inch projection screen. A sensor from a SomaneticsINVOS 3100 Cerebral Oxygen Monitor was placed on the forehead above the right eye Figure 1.

An infrared sensor from Nellcor N-200 Pulse Oximeter was placed on the left temple. Both sensors were secured to each subject's head by an elastic sports bandage Figure 2. The cerebral oxygen monitor and the pulse oximeter were linked to an IBM compatible 486 P.C., where a communication program (Telix)compiled the data in five-second intervals.

For thirty seconds prior to the start of the first experimental data run, subjects closed their eyes while pre-baseline data was gathered.

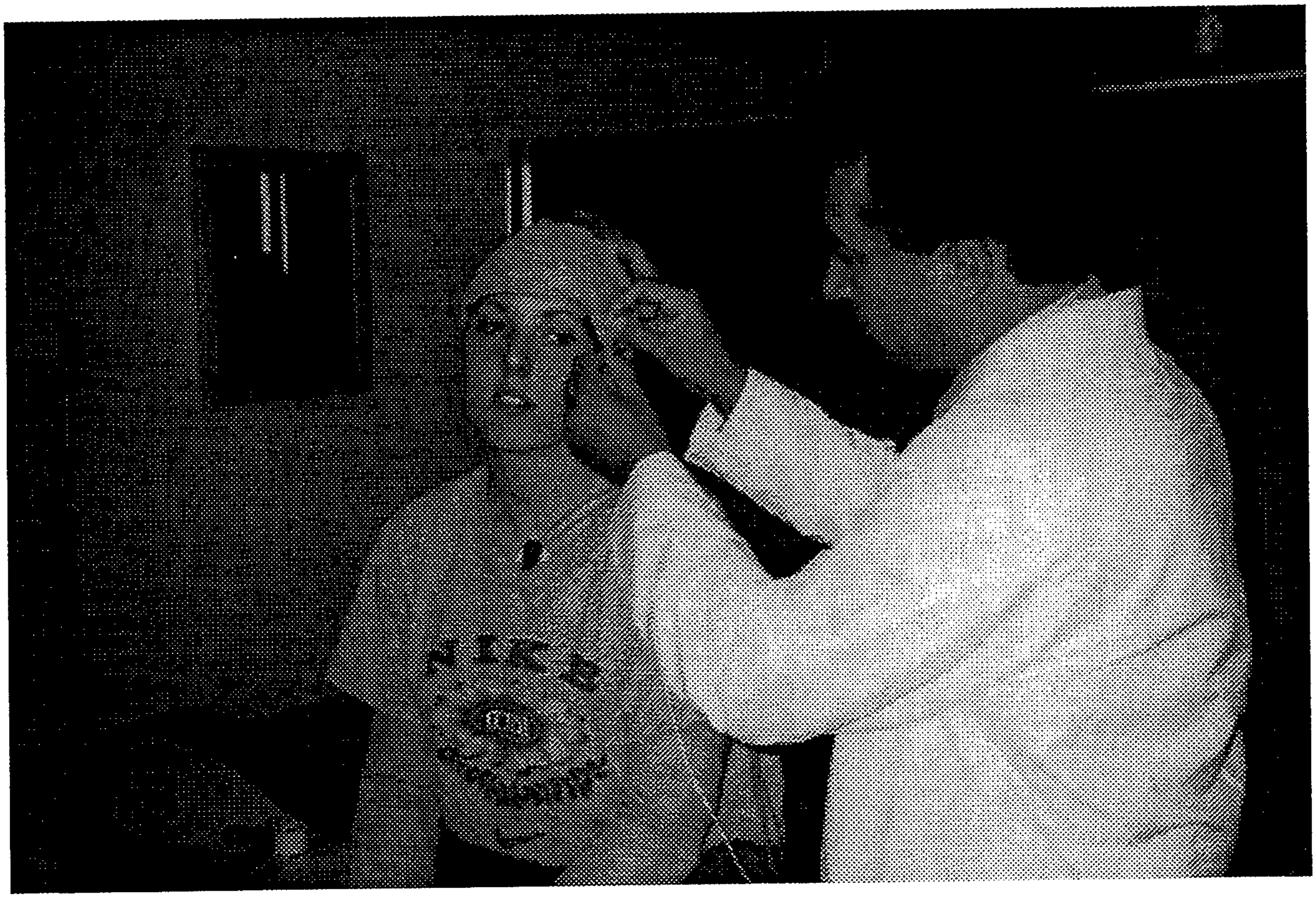


Figure 2. Nellcor N-200 arterial oxisensor.

Following pre-baseline, the flight simulation produced an image of the F-16 at 10,000 ft. directly aft of a target plane.

Subjects attempted to follow the target through various aerial maneuvers as accurately as possible, which produced simulated levels of +7Gz. The subjects were also asked to respond to call signals. After an average of four minutes, the flight simulation froze, signifying the end of the tracking task.

Subjects were asked to close their eyes as post-baseline data was gathered.

Pre- and post-baseline data collection for the second data run was gathered with the subjects' eyes open.

The same flight pattern from the first run was used, but the target plane's flight speed was increased **How Much?** The subjects' flight speed remained the same, increasing the difficulty of the tracking task. Subjects were asked again to respond to call signals. The average duration of the second flight was 2.7 minutes, shorter than the first flight because the target plane's speed was increased, but the starting and ending points of the target remained the same.

Subjects were asked to close their eyes during pre-and post-baseline data collection for the third and final run. The same flight pattern was used, but the target plane's flight speed was increased **How Much?** in addition to its speed in the second run. The subjects' flight speed remained the same. Subjects continued to respond to call signals. The average duration of the third flight was 2.2 minutes, the shortest of the three flights.

Results

Figures 3 illustrate the cerebral oxygen saturation levels of the four subjects. Event spikes indicated the beginning and end of the tracking task. In each of their second and third tracking task, none of the pilots were able to maintain visual contact for longer than approximately thirty seconds due to the imbalance of speed between the target and the pilot's aircraft. The complication was anticipated to produce noticeable physiological changes in cerebral blood flow and oxygen saturation. Correlation of the flight profiles with the data in the graph indicates a drop in cerebral blood flow in all four subjects early into the second or third run, approximately when the target plane flew out of visual range.

Simulated flight profiles were analyzed in six time tables: one thirty-second period immediately preceding the simulation, four time tables during the actual tracking procedure, and one thirty-second period immediately following the simulation. The three runs were averaged according to subject and time table. Results can be found in Table 1. Using single factor ANOVA, pre-baseline data was shown to be quite reliable ($p<.05$), whether the subjects' eyes were open or closed.

Statistically significant measurements may be found during early stages of each flight, including the noted decrease in cerebral oxygen levels. During second and third flights, subjects who were able to reestablish visual contact with the target, if only briefly, experienced a noticeable increase in cerebral oxygen levels. However, second and third runs for each subject revealed lower cerebral oxygen levels during the latter two time tables. Statistical reliability also fell, with 38% of average readings having a P-value greater than .05.

Factors possibly attributing the decreases include the dilation of the blood vessels for glucose metabolism, less than real-time flight simulation and reduced physiological response, or practice and fatigue order effects. For three of four subjects, post-baseline data was statistically significant, showing a decrease in cerebral oxygen levels from flight, again, whether the subjects' eyes were open or closed.

Conclusions

Pre- and Post-Baseline data can be collected with either the eyes open or close, with no significant variance. Cerebral oxygen levels do not provide a clear correlation between physiological reaction and mental workload. However, indication of such a correlation must require further investigation to define a psychophysiological relationship.

References

1. Bauer, L. O., R. Goldstein, and J. A. Stern. Effects of Information-Processing Demands on Physiological Response Patterns. *Human Factors*: Vol. 29 (2), pp. 213-234, 1987.

2. Fulton, J. F. Observations Upon the Vascularity of the Human Occipital Lobe During Visual Activity. *Brain*: Vol. 51, pp. 310-320, 1928.

3. Jorna, P. G. A. M. Heart Rate and Workload Variations in Actual and Simulated Flight. *Ergonomics*: Vol. 36 (9), pp. 1043-1054, 1993.

4. Lindholm, E. and C. M. Cheatham. Autonomic Activity and Workload During Learning of a Simulated Aircraft Carrier Landing Task. *Aviation, Space, & Environmental Medicine*: Vol. 54 (5), pp. 435-439, 1983.

5. Roscoe, A. H. Heart Rate as a Psychophysiological Measure for In-Flight Workload Assessment. *Ergonomics*: Vol. 36(9), pp. 11055-1062, 1993.

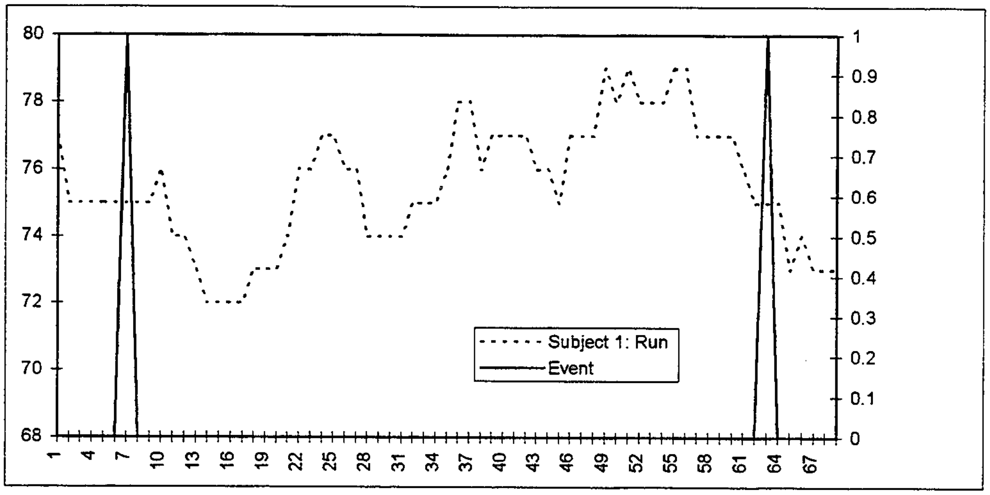
6. Sekiguchi, C., Y. Handa, M. Gotoh, Y. Kurihara, Y. Nagasawa, and I. Kuroda. Frequency Analysis of Heart Rate Variability Under Flight Conditions. *Aviation, Space, & Environmental Medicine*: Vol. 50 (6), pp. 625-634, 1979.

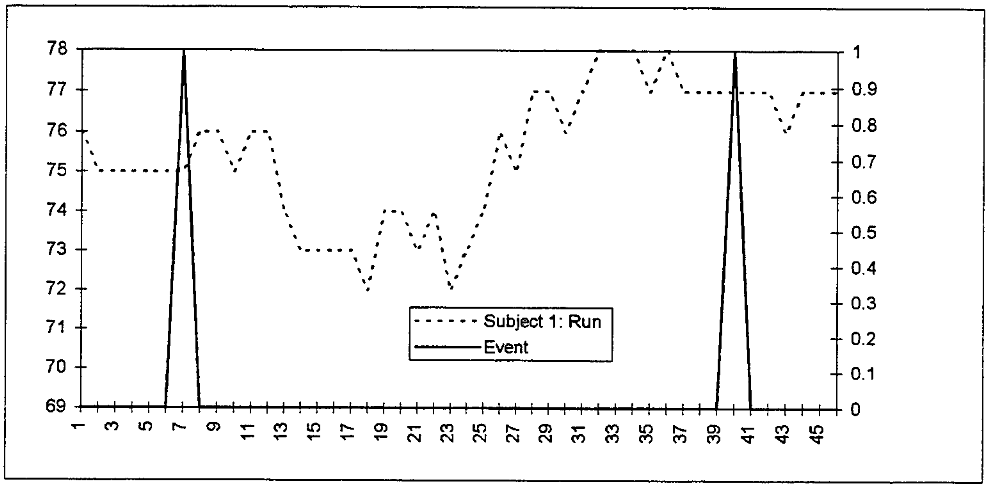
TABLE 1

SINGLE FACTOR ANOVA

		Pre-Baseline		Time Table 1		Time Table 2		Time Table 3		Time Table 4		Post-Baseline	
		Average Cerebral O2 (%)	Group P-Value	Average Cerebral O2 (%)	Group P-Value	Average Cerebral O2 (%)	Group P-Value	Average Cerebral O2 (%)	Group P-Value	Average Cerebral O2 (%)	Group P-Value	Average Cerebral O2 (%)	Group P-Value
Subject 1	Run 1	75.3333333		73.5		75.2142857		76.7142857		77.6428571		73.5	
	Run 2	75.1666667	0.00024978	75.125	6.2421E-07	73.25	9.6722E-06	75	0.01307193	77.5	0.77256097	76.8333333	1.1277E-06
	Run 3	76.8333333		77.2857143		75.875		76.2857143		77.25		76.1666667	
Subject 2	Run 1	72.1666667		72.8181818		73		73.0909091		74.4545455		73	
	Run 2	72.1666667	0.03637965	72.75	0.00010959	71.875	5.6482E-05	73.25	0.25274211	73.5	0.02899839	72.5	0.01535859
	Run 3	71.3333333		71.6666667		72.3333333		73.6666667		74.3333333		73.3333333	
Subject 3	Run 1	71		70.2727273		70.6363636		70.5454545		71.2727273		71.1666667	
	Run 2	71	0.02168375	71.2857143	0.00201881	70.375	0.05438622	70.7142857	0.15663799	70.75	0.0102341	71	0.11560044
	Run 3	70.5		71		71		71		70.3333333		70.5	
Subject 4	Run 1	63		62.4545455		64.25		63.9090909		65.6666667		63.6666667	
	Run 2	65.1666667	8.7441E-11	64.2222222	3.0391E-05	64.3333333	9.8775E-05	64.8888889	0.00018851	63.3333333	1.4503E-08	64.25	0.09133154
	Run 3	65		64		63.1666667		63.5		64.6666667		64.3333333	

Table 1 - Cerebral Oxygen Level Averages Using Single Variable ANOVA





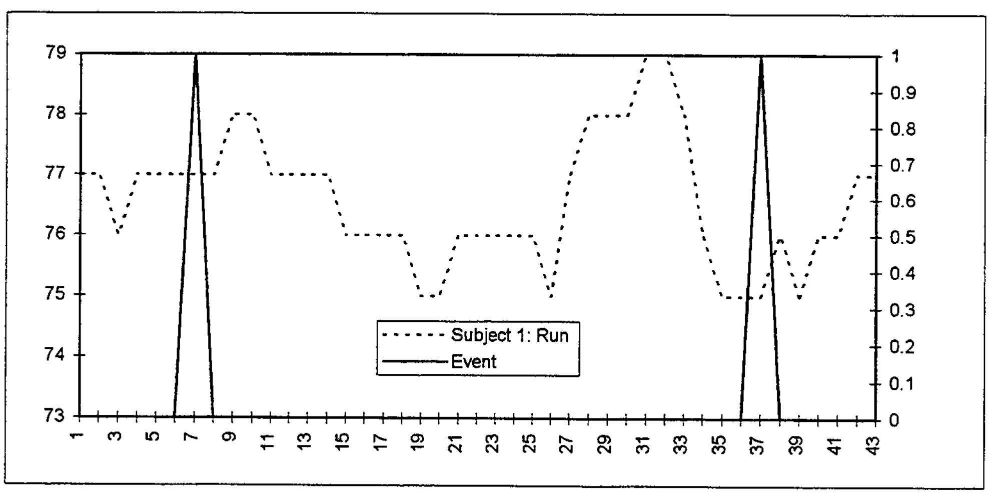
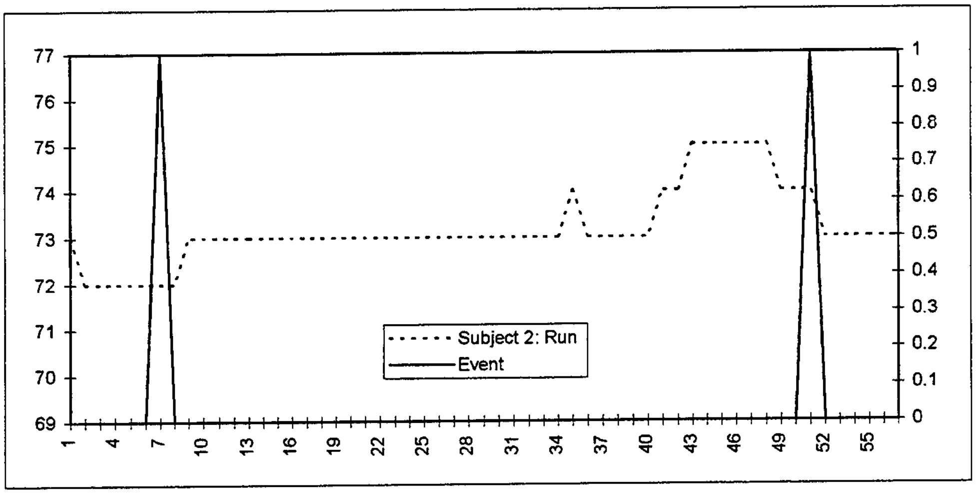
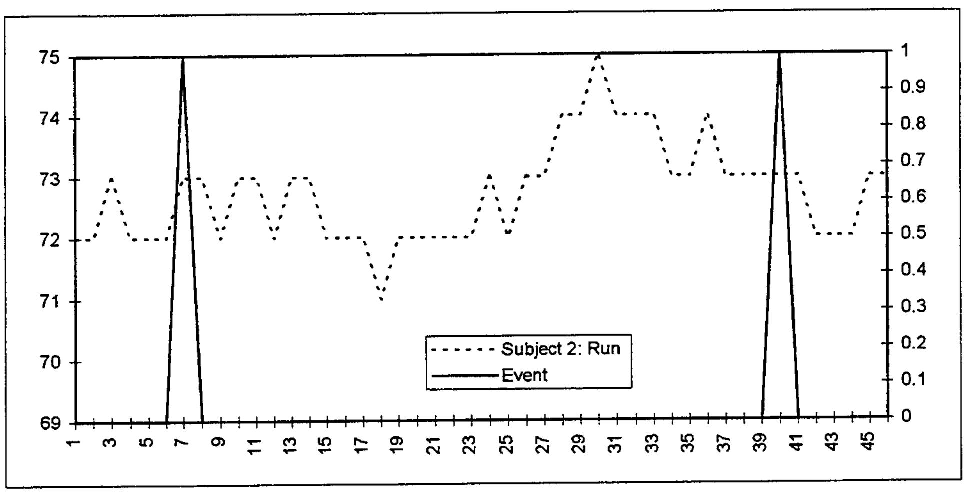


Figure 3 - Subject Cerebral Oxygen Profiles





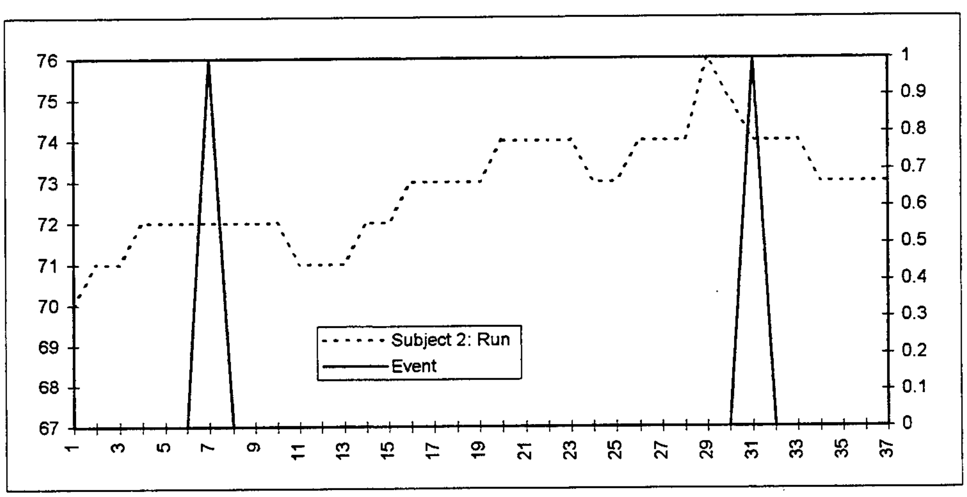
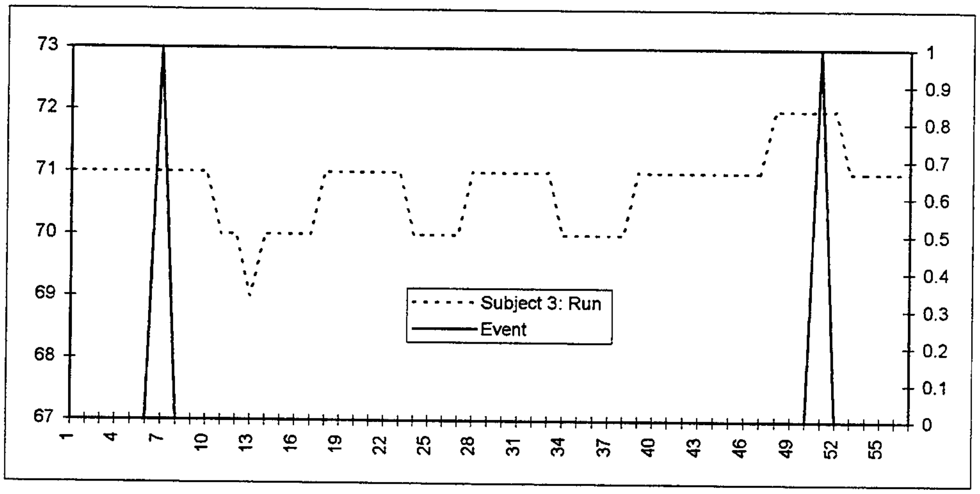
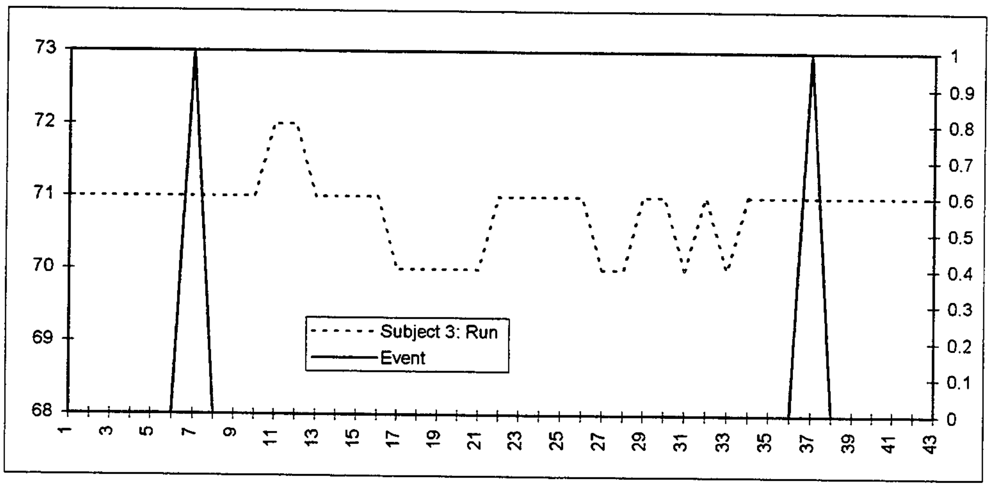


Figure 3 - Subject Cerebral Oxygen Profiles





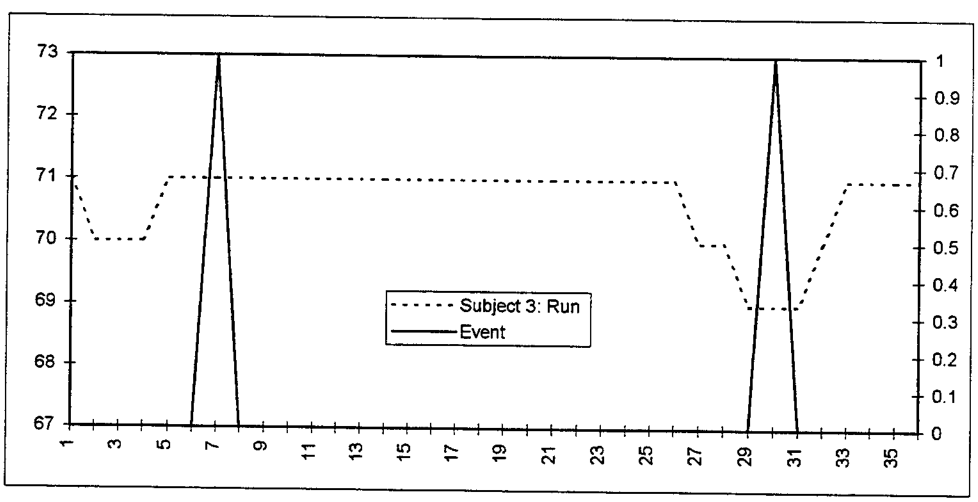
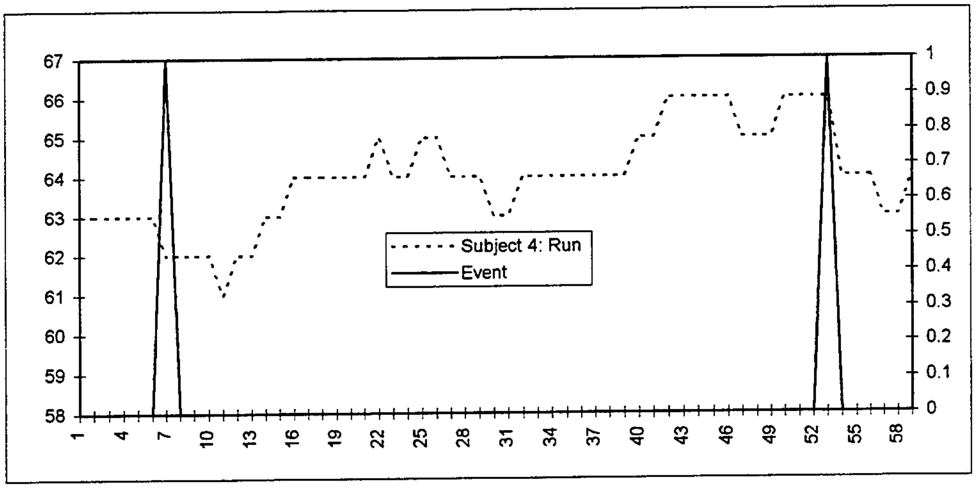
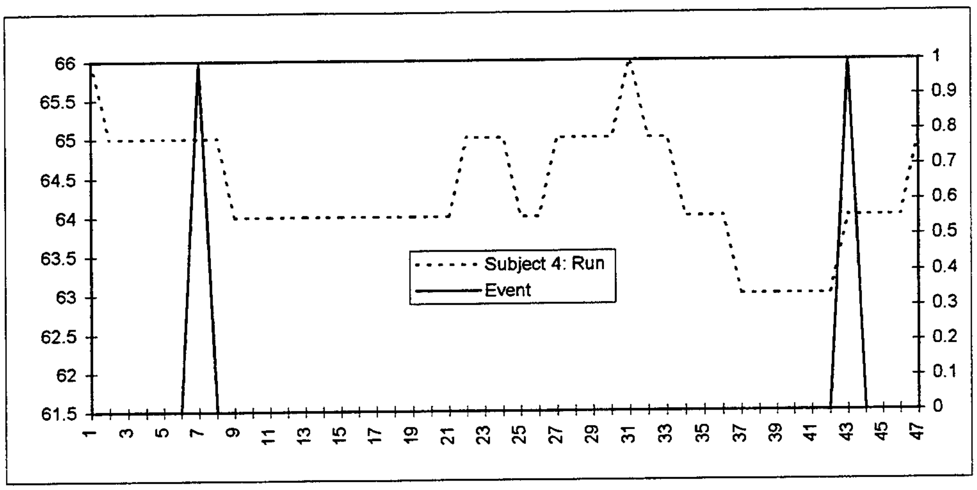


Figure 3 - Subject Cerebral Oxygen Profiles





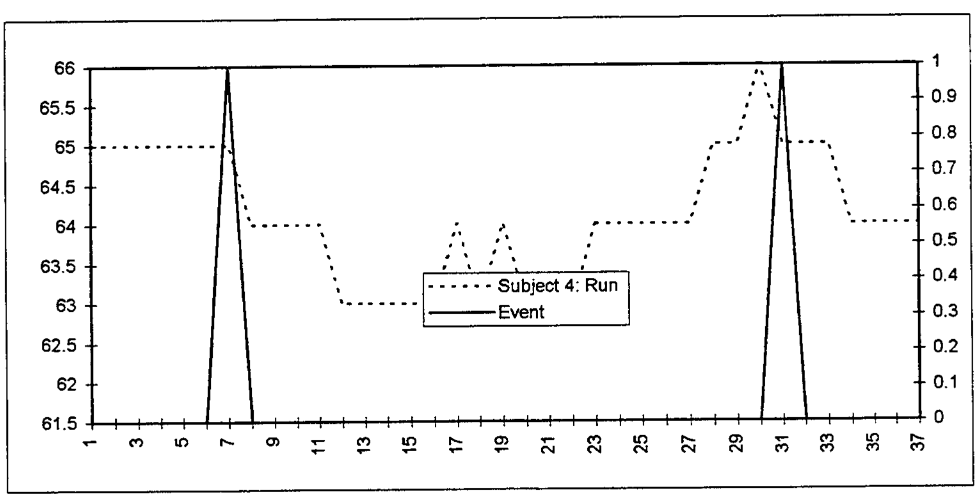


Figure 3 - Subject Cerebral Oxygen Profiles

Analysis of Human Muscle Movement Under Increased Acceleration

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Final Report for:
High School Apprentice Program
Armstrong Laboratory

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East Central High School

Abstract

Analysis of experimental data was conducted to better understand human movements in an increased gravitational environment. Thirteen subjects were asked to perform a sequence of rising from a chair, and jumping movements at increased G levels. The subjects completed these movements on three separate days at each of the following G levels: 1.0, 1.2, 1.4, 1.6, 1.8, 1.6, 1.4, 1.2, 1.0. Subject data was collected using electromyographic electrodes, 2 force plates (1 ground, and 1 seat), video camera, and protective balance bar. The force applied to the bar (strain gauge), and force plates were recorded for later analyses. Four leg muscles (gastrocnemius, vastus lateralis, semitendinous, and gluteus maximus) were monitored and recorded during their movements. Initial analysis indicates subjects were able to perform all of the movements at all of the G levels. There is also an indication that a training effect is taking place.

Analysis of Human Muscle Movement

Under Increased Acceleration

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Introduction

All experimental data was collected approximately two years ago. Each subject performed the sit to stand and jumping experiment three times at each G level. During the experiment the G level is raised from 1.0 G to 1.8 G and back down to 1.0 G (d) (see figure 1). The "d" is the label for the decreasing G level.

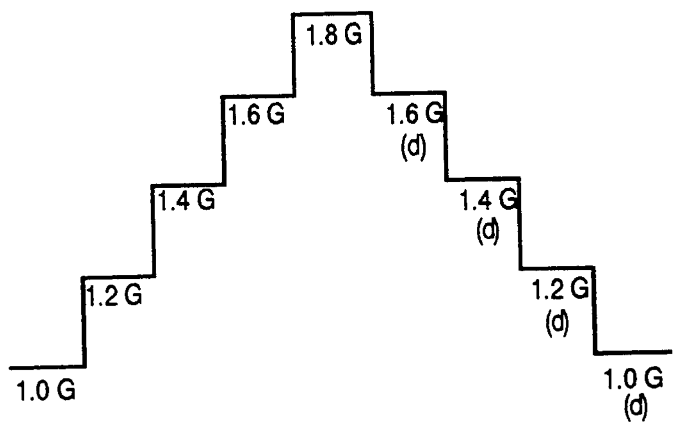


Figure1. G profile for experiment

I first converted all the data that was in binary form and transferred it to ASCII files for further analysis with programs written in Labview 3. The following are the binary data columns that were converted and written out to an ASCII file (nine columns):

Binary Data Columns

(1) Ground Reaction Force

(2) Seat

(3) Bar

(4) Accelerometer One

(5) Accelerometer Two

(6) Gastrocnemius

(7) Vastus Lateralis

(8) Hamstring

(9) Gluteus Maximus

A program called Final Calculations was written to convert data from volts to "real" values such as: ground reaction force and the bar force to Newtons; accelerometers to (m/s2);and electromygraphic (EMG) signals to volts for further calculations. The Final Calculations program was created to read ASCII data files and compute some basic parameters. These parameters are written out to stat files. These stat files are divided into twenty-two columns:

<u>Stat Files</u>

(1) Subject

(2) Sex Code

(3) Day

(4) G-Level

(5) Mass

(6) Jump Height

(7) Jump Time

(8) Peak Acceleration

(9) Peak Acceleration Index

(10) Peak Power

(11) Peak Power Index

(12) Muscle Power

(13) Total Peak Power

(14) Total Peak Power Index

(15) Average Total Peak Power

(16) Final Velocity

(17) Final Displacement

(18) Energy Integrated

(19) Total Calculated

(20) Total Energy

(21) Start Index

(22) Stop Index

Methodology

Graphing was done to identify the noticeable differences between the data collected for the three days, for the same subject. Due to time constraints the EMG program was only run on a single subject for three days. All of the stat data for each jump was copied into an Excel worksheet and broken down into the twenty-two columns. The start and stop indexes were then printed out so that they could be input into the EMG programs. The jumping data was then separated by G levels, and an average for the parameter was determined by averaging the data over each G level.

The resulting graphs were printed out for easier comparison and a selected few are included in the Appendix. The graphs were compared based on G levels, and performance. Several differences were seen in this subject. Figure 2a is a sample print out of an entire jump at 1.0 G. The first graph shows the subject's jump from standing, through the jump, and landing. The force generated as the subject takes off peaks at 2000 N. During the time the subject is in the air the signal drops to zero, and returns to approximately 2200 N as the subject lands. The following four graphs illustrate the signals representing muscle activity during the jump.

Figure 2b is an example of the portion of the jump that is needed for analysis. Instead of showing the entire jump it shows the ground reaction force and the muscle activity present before and during take off. There are six graphs per print out for each of the three days: four are the electromyography (EMG)

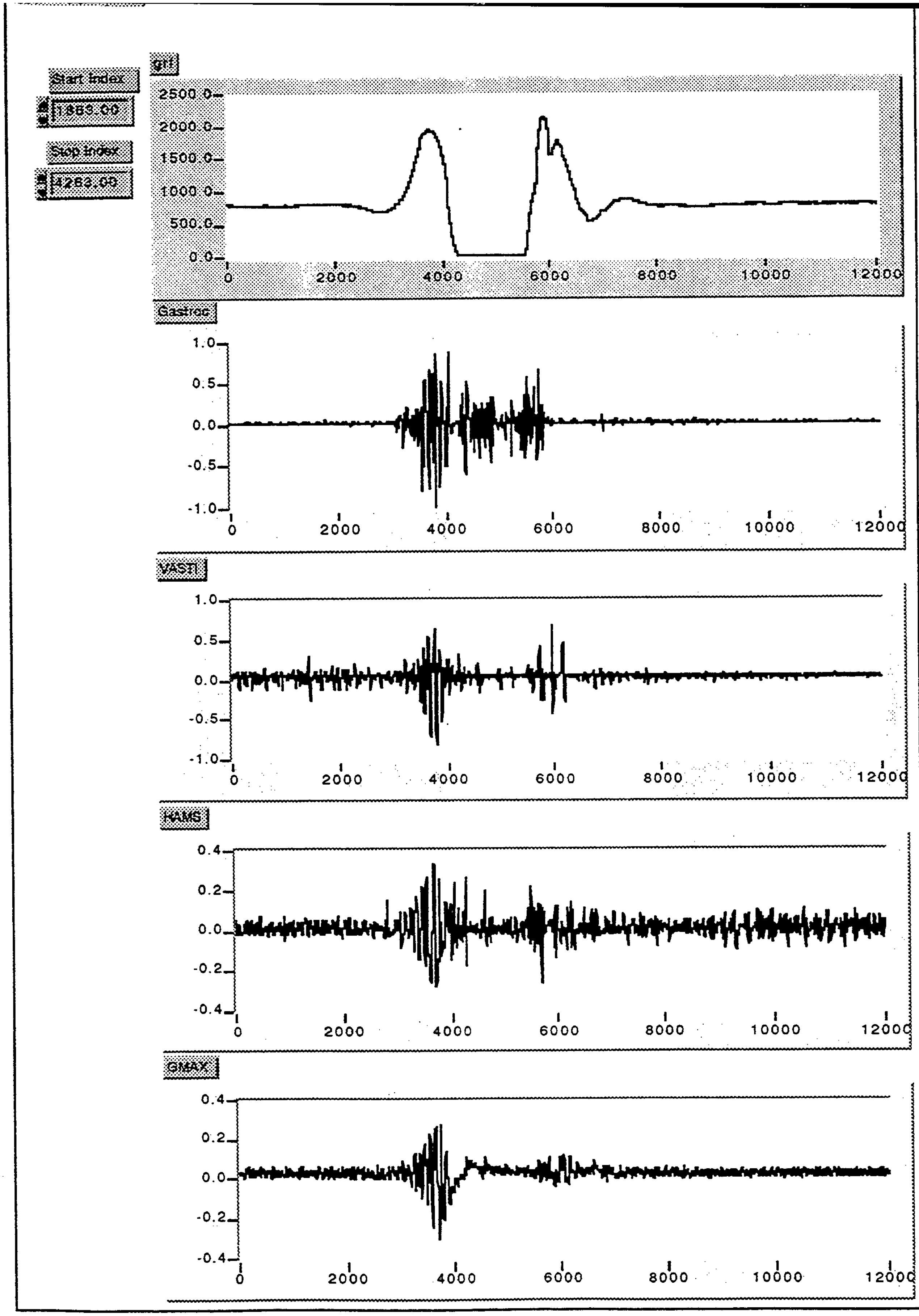


Figure 2a.

Full 3 seconds of data for one subject.

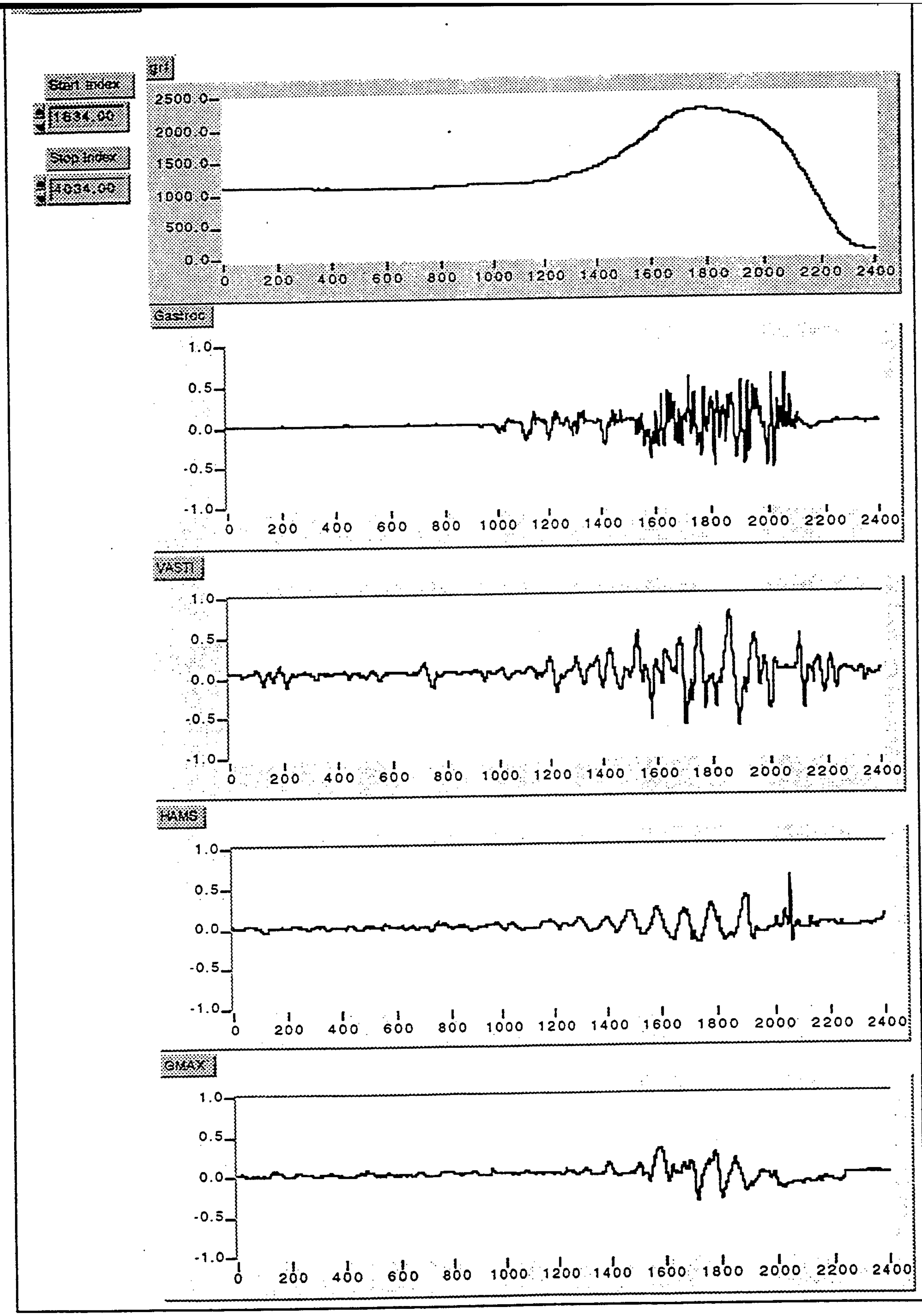


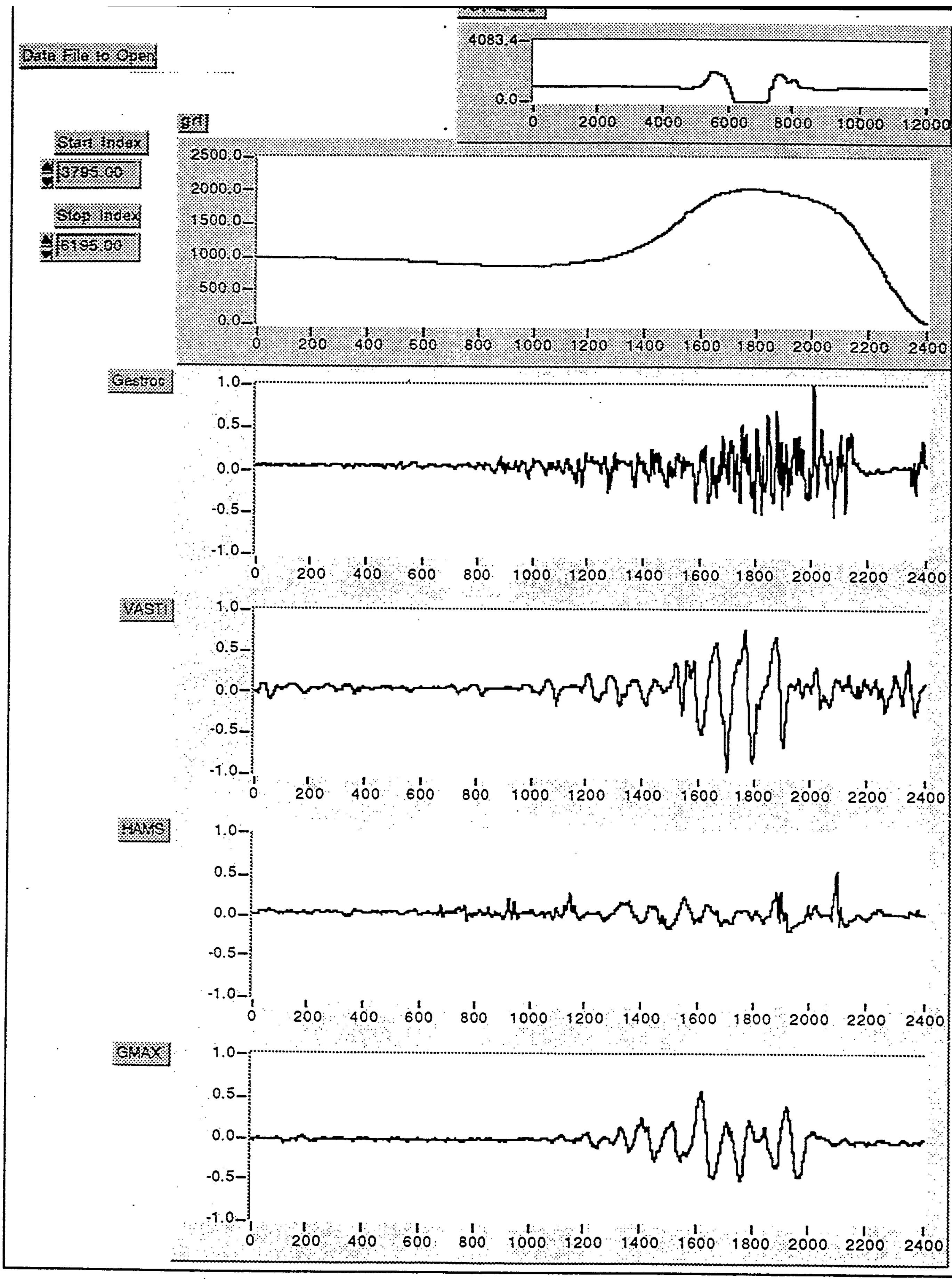
Figure 2b.
Section of data representing standing through toes-off.

graphs, and the other two are the ground reaction force. From these six graphs generalizations can be made as to what muscles were active, for what time frame and at what G level. The numbers on the x axis represents data points in hertz. To convert to seconds, divide the data point (0-2400) by 4000.

At 1.0 G the vasti muscle was active at .225 sec on day one; on the second the amplitude was greater and it started at .3250 sec; on the third day the amplitude was double what it was on the second day and started at approximately .3250 sec. The EMG graph shows for the same three days that the hamstring remained constant with little change in the amplitude or time. The gluteus maximus on the other hand was totally inactive on day one, activity started at .25 sec and stopped at .5250 sec, and on the third day started at .3000 and stopped at .5000 sec, with approximately the same amount of amplitude range. At 1.2 G the three days vary greatly. On day one all four muscles are very active and all start at approximately .2000 sec; on day two gastroc is active at .2500 sec while vasti and hamstrings remain the same, and gluteus maximus is higher in amplitude and starts at .3250 sec. On the third day at 1.2 G all muscles are inactive except vasti with a very low reading in amplitude and barely reads as an active muscle. At 1.4 G muscle activity is greatest on day one in gastroc and vasti, and only moderate in hamstrings, and gluteus maximus. All four muscle signals start at .3000 sec and stop at .5750 sec. Although on the second and third day there is no activity at all for gastroc, hamstrings, and gluteus maximus, and only a slight signal is received for vasti. Once raised to 1.6 G the muscle signals become very active and similar. The start and stop times for the signals are the same. The only difference is with the range of amplitude. On day two the gastroc signal has extremely high amplitude, but the amplitude is the same on day one and two. At the highest G level used in this experiment (1.8 G), the hamstrings and the gluteus maximus are identical. The gastroc muscle maintains the same amplitude on both day one and two, but on the third day the gastroc signal decreases to almost nothing. Vasti, on the other hand, increases with each day in the amount of amplitude each signal contains. During the 1.6 G (d) jump gastroc has no sign of activity for day one or three, but on day two there is a stronger gastroc signal; it has more amplitude and starts sooner at .1750 sec. The other three muscles are all similar and have signals starting relatively at the same time. The only noticeable difference is in vasti; although the signal patterns are similar the amplitude increases as the days increase. At the 1.4 G (d) for the third day the electromyography surface patch monitoring the gastroc muscle disconnected for the last three G levels therefore, the signal and data was lost. The peak frequency and the amplitude for the hamstrings and the gluteus maximus strongly resemble each other. While the day one vasti signal is very active, the last two day's amplitude reading registers off the scale. Graphs show that at 1.2 G (d) there is increasingly less gastroc activity and both vasti and gluteus maximus remain moderate. The last G level 1.0 G (d) indicates that the last two days the same muscles were active, and almost mirrored each other in amplitude, and frequency.

Conclusion

After analyzing the graphs some initial observations can be made. Day two and three seem to resemble each other more then Day one. Conceivably this may indicate several things: one that the subject was no longer nervous, or that a training effect is taking place. This would imply that the subject was anticipating the requirements to jump better or to better adapt to the surrounding increased gravitational environment. The EMG muscle activity may possibly identify some adaptations developing in the last two days. All subjects were able to safely perform the experiment. Much more analysis is needed to better identify causes for the differences seen in this sample study.



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Gastroc
VASTI
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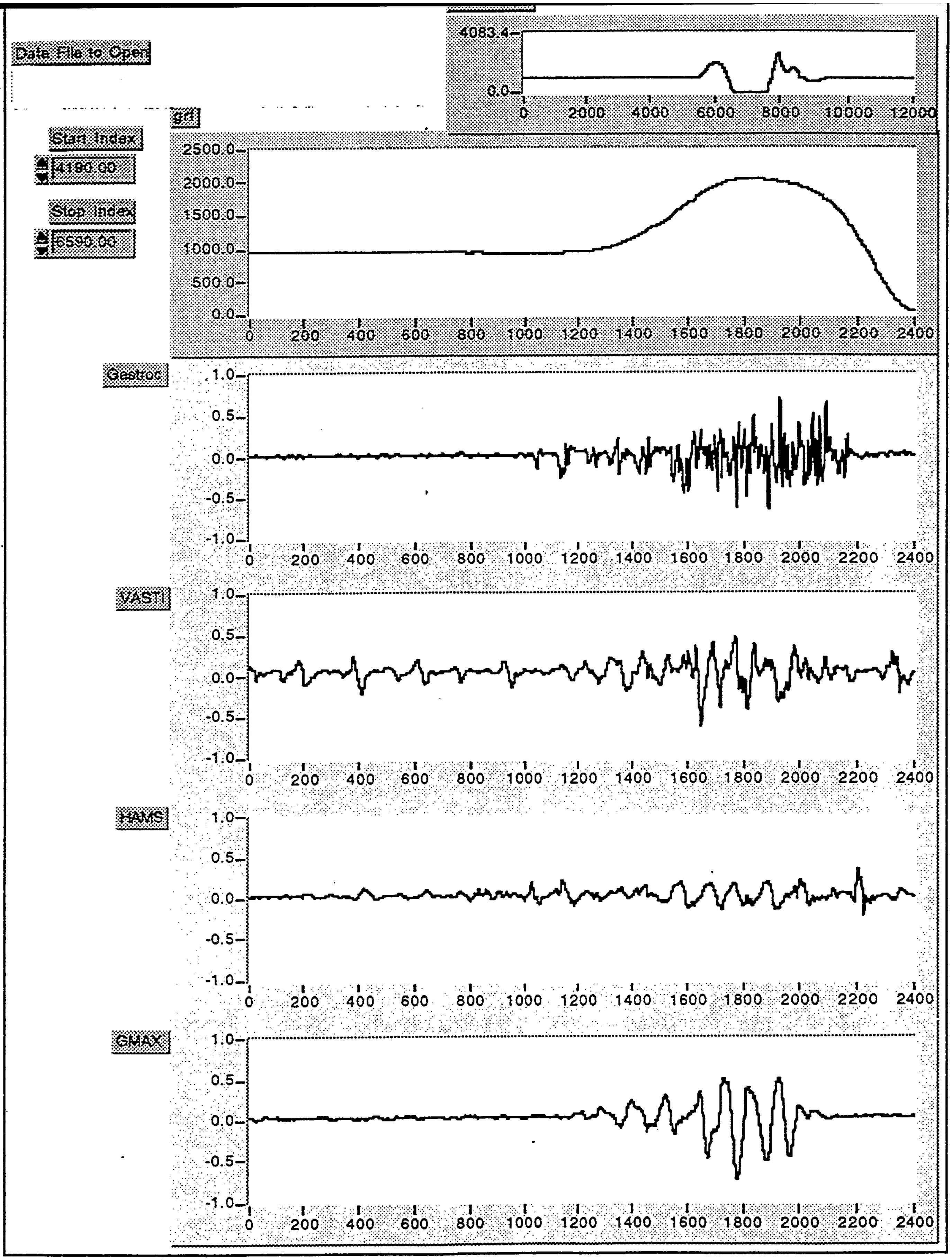

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Gastroc
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